VOLUME TWO

ECOLOGICAL INVESTIGATIONS

PEACE-ATHABASCA DELTA PROJECT

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ECOLOGICAL INVESTIGATIONS

Prepared by
The Peace-Athabasca Delta Project Group
Canada Alberta Saskatchewan

A CO-OPERATIVE INTERGOVERNMENTAL STUDY ESTABLISHED BY THE ENVIRONMENTAL MINISTERS OF CANADA, ALBERTA AND SASKATCHEWAN

HON. W. J. YURKO for Alberta
HON. JACK DAVIS for Canada
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FOREWORD

In January 1971, the Governments of Canada, Alberta, and Saskatchewan established a cooperative interdisciplinary study group to investigate and report on the cause and effects of low water levels in Lake Athabasca. The focus of the investigations was directed towards determining the effects of low levels on the Peace-Athabasca Delta located at the West end of Lake Athabasca and on the people of the area.

The information contained in this report covers the ecological studies carried out under the Peace-Athabasca Delta Project. The complete report consists of:

- Summary Report, 1972
- Technical Report
- Volume 1, Hydrologic Investigations
- Volume 2, Ecological Investigations
- Volume 3, Support Studies

The Technical Report provides a detailed analysis of the cause and effects of the low water levels and recommendations for remedial action. Volumes 1 and 2 contain detailed reports on the hydrologic and ecological investigations. The Summary Report, based on the Technical Report but presented in nontechnical language for public distribution, briefly describes the various technical and management aspects of the Project.

The ecological investigations were coordinated by Gerald H. Townsend, who was seconded to the Project by the Canadian Wildlife Service. Technical advice in structuring the studies was provided by an ecological components committee composed of representatives from the Alberta Department of Lands and Forests

(Fish and Wildlife Division), Canada Fisheries Service, the Canadian Wildlife Service, Ducks Unlimited (Canada), the Inland Waters Branch (Water Quality Section), the National and Historic Parks Branch, the Saskatchewan Department of Natural Resources (Fisheries and Wildlife Branch), and the University of Alberta. The Peace-Athabasca Delta Project provided logistic and office support for the ecological investigations.

The first four papers include species lists of plants, fishes, birds and mammals occurring on the Delta. Sections E, F, and G describe the status of three fish species, the walleye, goldeye and lake trout, inhabiting the Delta and Lake Athabasca. The next section contains information on plankton and bottom invertebrates of the Delta lakes and marshes.

Sections I and J describe the major wildlife habitats of the Delta, how much is present and where, and how the vegetation changes over time due to plant succession. Next are four papers which discuss the status of waterfowl, muskrat, bison and moose on the Peace-Athabasca Delta. Finally, Appendix O describes a wildlife computer model written to predict effects of water level changes on habitat and populations of the major wildlife species.

The contribution of all individuals and agencies who participated in the preparation of these reports is gratefully acknowledged.

The Peace-Athabasca Delta Project Group adopted the policy that the participating agencies were responsible for the individual

reports prepared for the project. The views and opinions expressed in the appendices are therefore not necessarily those of the Project Group.

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R. P. Johnson, Saskatchewan Department of Natural Resources, Saskatoon, 1971.

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D. N. Gallup, P. Van der Giessen, H. Boerger, Department of Zoology, University of Alberta, Edmonton, 1971.

I Vegetation Mapping and Topography of the Peace-Athabasca Delta.
G. H. Townsend, Canadian Wildlife Service, Edmonton, 1972.

J Trends in Vegetation Succession in the Peace-Athabasca Delta.
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SECTION A

A CHECKLIST OF PLANTS COLLECTED

ON THE

PEACE-ATHABASCA DELTA

by

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From mid-summer 1968 to fall 1971, the Canadian Wildlife Service carried out landform/vegetation classification and plant successional trend studies in the Peace-Athabasca Delta. In the course of the field research carried out, vascular plants and Bryophytes were collected throughout the 1,700 square mile (4403 Km.^{2}) Delta complex.

The following list is derived from 543 collections which include 56 families, 143 genera and 252 species of vascular plants. Bryophyte collections have not been listed pending identification verification.

Identification of the vascular plants have been verified by Dr. V. L. Harms of the Fraser Herbarium, University of Saskatchewan, Saskatoon. Dr. G. Argus, Department of Environment, Forestry Branch, verified identification of the numerous Salix species collected. Voucher specimens are deposited in the Prairie Migratory Bird Research Centre, University of Saskatchewan, Saskatoon.

Scientific and common nomenclature are according to Moss (1959) and Cormack (1967).

ALISMACEAE

Broad-leaved water plantain	Alisma plantago - aquatica L.
Arrowhead	Sagittaria cuneata Sheld.

ARACEAE

Water arum	Calla palustris L.

ARALIACEAE

Wild sarsaparilla	Aralia nudicaulis L.

BETULACEAE

Alder	*Alnus incana* (L.) Moench.
River alder	*A. tenuifolia* Nutt.
Alder	*A. viridis* (Chaix.) D.C.
Dwarf birch	*Betula glandulosa* Michx.
Canoe birch	*B. papyrifera* Marsh. Var. *neolaskana* (Sarg.) Raup

BORAGINACEAE

Beggar-ticks	*Lappula redowskii* (Hornem.) Greene Var. *occidentalis* (Wats.) Rydb.
Bluebells	*Mertensia paniculata* (Ait.) G. Don

CALLITRICHACEAE

Water starwort	*Callitriche palustris* L.

CAMPANULACEAE

Common bluebell	*Campanula rotundifolia* L.

CAPRIFOLIACEAE

Twin-flower	*Linnaea borealis* L. Var. *americana* (Forbes) Rehd.
Twining honeysuckle	*Lonicera diocia* L. Var. *glaucescens* (Rydb.)
Butters	
Wolfberry	*Symphoricarpos occidentalis* Hook.
Low bush cranberry	*Viburnum edule* (Michx.) Raf.

CARYOPHYLLACEAE

Sandwort	*Arenaria lateriflora* L.
Sandwort	*A. stricta* (Michx.) ssp. *dawsonensis* (Britt.)
Maguire	
Mouse-ear chickweed	*Cerastium arvense* L.
Sand spurry	*Spergularia marina* L.
Chickweed	*Stellaria crassifolia* Ehrh.
Long-stalked chickweed	*S. longipes* Goldie

CERATOPHYLLACEAE

Hornwort	*Ceratophyllum demersum* L.

CHENOPODIACEAE

Lamb's quarters	*Chenopodium album* L.
Oak-leaved goosefoot	*C. glaucum* L. ssp. *salinum* (Standl.) Aellen
Maple-leaved goosefoot	*C. hybridum* L. Var. *gigantospermum* (Aellen) Rouleau
Red goosefoot	*C. rubrum* L.

CISTACEAE

Sand heather	*Hudsonia tomentosa* Nutt. Var. *intermedia* Peck

COMPOSITAE

Common yarrow	*Achillea millefolium* L. Var. *nigrescens* E. Meyer
Common yarrow	*A. millefolium* L. ssp. *lanulosa* (Nutt.) Piper
	A. sibirica Ledeb.
Pussy-toes	*Antennaria microphylla* Rydb.
Everlasting	*A. neglecta* Greene
Small-flowered everlasting	*A. nitida* Greene
Rosy everlasting	*A. rosea* Greene
Arnica	*Arnica lonchophylla* Greene
Biennial sagewort	*Artemisia biennis* Willd.
Pasture sagewort	*A. frigida* Willd.
Rayless aster	*Aster brachyactis* Blake
Western willow aster	*A. hesperius* A. Gray
Purple stemmed aster	*A. puniceus* L.
Nodding beggar-ticks	*Bidens cernua* L.
Fleabane	*Erigeron philadelphicus* L.
Arrow-leaved coltsfoot	*Petasites sagittatus* (Pursh) A. Gray
Marsh ragwort	*Senecio congestus* (R.Br.) DC.
	S. eremophilus Richards.
	S. cymbalarioides Nutt.
Goldenrod	*Solidago canadensis* L.
	S. graminifolia (L.) Salisb.
Perennial sowthistle	*Sonchus arvensis* L.
Common dandelion	*Taraxacum officinale* Weber

CORNACEAE

Bunchberry	*Cornus canadensis* L.
Red osier dogwood	*C. stolonifera* Michx.

CRUCIFERAE

Rock cress	*Arabis hirsuta* (L.) Scop.
Rock cress	*A. lyrata* L.
Winter cress	*Barbarea orthoceras* Ledeb.
Bitter cress	*Cardamine pensylvanica* Muhl.

Green tansy mustard	*Descurainia pinnata* (Walter) Britton
	D. pinnata (Walt.) Britt. Var. *brachycarda* (Rich.) Fern.
Tansy mustard	*D. sophia* (L.) Webb
Draba	*Draba nemorosa* L. Var. *leiocarpa* Lindbl.
Yellow cress	*Rorippa islandica* (Oeder) Borbas

CYPERACEAE

Sedge	*Carex aenea* Fern.
Sedge	*C. aquatilis* Wahl.
Sedge	*C. atherodes* Spreng.
Sedge	*C. concinna* R.Br.
Sedge	*C. crawfordii* Fern.
Sedge	*C. diandra* Schrank
Sedge	*C. foenea* Willd.
Sedge	*C. obtusata* Lilj.
Sedge	*C. richardsonii* R.Br.
Sedge	*C. rostrata* Stokes
Sedge	*C. stipata* Muhl.
Sedge	*C. synchnocephala* Carey
Spike rush	*Eleocharis acicularis* (L.) R. & S.
Spike rush	*E. palustris* (L.) R. & S.
Cotton grass	*Eriophorum chamissonis* C.A. Mey
	E. vaginatum L. ssp. *spissum* (Fern.) Hulten
Hardstem bulrush	*Scirpus acutus* Muhl.
Softstem bulrush	*S. validus* Vahl.

ELAEGNACEAE

Canadian buffalo-berry	*Shepherdia canadensis* (L.) Nutt.

EMPETRACEAE

Crowberry	*Empetrum nigrum* L.

EQUISETACEAE

Common horsetail	*Equisetum arvense* L.
	E. fluviatile L.
	E. palustre L.
	E. pratense Ehrh.

ERICACEAE

Common bearberry	_Arctostaphylos uva-ursi_ (L.) Spreng.
Leather-leaf	_Chamaedaphne calyculata_ (L.) Moench
Mountain laurel	_Kalmia polifolia_ Wang
Common labrador tea	_Ledum groenlandicum_ Oeder
Blueberry	_Vaccinium myrtilloides_ Michx.
Bog cranberry	_V. vitis-idaea_ L. Var. _minus_ Lodd.

FUMARIACEAE

Pink corydalis	_Corydalis sempervirens_ (L.) Pers.

GENTIANACEAE

Northern gentian	_Gentianella amarella_ (L.) Borner

GRAMINEAE

Crested wheat grass	_Agropyron cristatum_ (L.) Gaertn.
Slender wheat grass	_A. trachycaulum_ (Link) Malte
Hairgrass	_Agrostis scabra_ Willd.
Water foxtail	_Alopecurus aequalis_ Sobol.
Northern awnless brome	_Bromus pumpellianus_ Scribn.
Marsh reed grass, bluejoint	_Calamagrostis canadensis_ (Michx.) Beauv.
Northern reed grass	_C. inexpansa_ A. Gray
Purple reed grass	_C. purpurascens_ R.Br.
Drooping wood reed	_Cinna latifolia_ (Trev.) Griseb.
Tufted hair grass	_Deschampsia caespitosa_ (L.) Beauv.
Hairy wild rye	_Elymus innovatus_ Beal
Fescue	_Festuca saximontana_ Rydb.
Manna grass	_Glyceria borealis_ (Nash.) Batchelder
	G. grandis S. Wats.
Sweetgrass	_Hierochloe odorata_ (L.) Beauv.
Rice grass	_Oryzopsis pungens_ (Torr.) Hitchc.
Reed canary grass	_Phalaris arundinacea_ L.
Common reed	_Phragmites communis_ Trin.
Alpine bluegrass	_Poa alpina_ L.
Bluegrass	_P. arctica_ R.Br.
Bluegrass	_P. canbyi_ (Schribn.) Piper
Bluegrass	_P. glauca_ Vahl.
Bluegrass	_P. interior_ Rydb.
Fowl bluegrass	_P. palustris_ L.
Kentucky bluegrass	_P. pratensis_ L.

Alkali grass	*Puccinellia nuttalliana* (Schult.) Hitchc.
False melic	*Schizachne purpurascens* (Torr.) Swallen
Whitetop	*Scolochloa festucacea* (Willd.) Link
Porcupine grass	*Stipa spartea* Trin.
Spike trisetum	*Trisetum spicatum* (L.) Richt.

HALORAGIDACEAE

Water milfoil	*Myriophyllum* sp.

HIPPURIDACEAE

Mare's tail	*Hippuris vulgaris* L.

HYDROPHYLLACEAE

Scorpion weed	*Phacelia franlinii* (R.Br.) A. Gray

IRIDACEAE

Blue-eyed grass	*Sisyrinchium montanum* Greene

JUNCACEAE

Rush	*Juncus alpinus* Vill.
Wire rush	*J. balticus* Willd.
	J. brevicaudatus (Engelm.) Fern.
Toad rush	*J. bufonius* L.

LABIATAE

Hedge nettle	*Stachys palustris* L. Var. *pilosa* (Nutt.) Fern.

LEGUMINOSAE

Milk vetch	*Astragalus alpinus* L.
Wild sweet pea	*Lathyrus ochroleucus* Hook.
White clover	*Trifolium repens* L.
Wild vetch	*Vicia americana* Muhl.

LEMNACEAE

Common duckweed	*Lemna minor* L.
	L. trisulca L.

LENTIBULARIACEAE

Flat-leaved bladderwort	*Utricularia intermedia* Hayne
Common bladderwort	*U. vulgaris* L.

LILIACEAE

Wild lily-of-the-valley	*Maianthemum canadense* Desf.
Star-flowered Solomon's seal	*Smilacina stellata* (L.) Desf.

LYCOPODIACEAE

Ground cedar	*Lycopodium complanatum* L.

NAJADACEAE

Pondweed	*Potamogeton gramineus* L.
Pondweed	*P. natans* L.
Sago pondweed	*P. pectinatus* L.
Pondweed	*P. pusillus* L.
Clasping-leaf pondweed	*P. richardsonii* (Benn.) Rydb.
Large-sheath pondweed	*P. vaginatus* Turcz.
Pondweed	*P. zosteriformis* Fern.

NYMPHAEACEAE

Yellow pond-lily	*Nuphar variegatum* Englm.

ONAGRACEAE

Enchanter's nightshade	*Circaea alpina* L.
Common fireweed	*Epilobium angustifolium* L.
	E. glandulosum Lehm.
	E. palustre L.

ORCHIDACEAE

Rattlesnake plantain	*Goodyera oblongifolia* Raf.
Bracted bog orchid	*Habenaria viridis* (L.) R.Br. Var. *bracteata* (Muhl.) A. Gray

PLANTAGINACEAE

Common plantain	*Plantago major* L.

POLEMONIACEAE

Collomia	*Collomia linearis* Nutt.

POLYGONACEAE

Water smartweed	*Polygonum amphibium* L.
Common knotweed	*P. aviculare* L.
Smartweed	*P. lapathifolium* L.
	P. prolificum (Small) B.C. Robins
Golden dock	*Rumex maritimus* L. Var. *fueginus* (Phil.) Dusen
Narrow-leaved dock	*R. mexicanus* Meisn.
Western dock	*R. occidentalis* S. Wats.
Narrow-leaved dock	*R. salicifolius* Weinm. (*mexicanus* Meisn.)

POLYPODIACEAE

Bladder fern	*Cystopteris fragilis* (L.) Bernh.
Fragrant shield fern	*Dryopteris fragrans* (L.) Schott
Oak fern	*Gymnocarpium dryopteris* (L.) Newm.
Common polypody	*Polypodium vulgare* L.
Rusty woodsia	*Woodsia ilvensis* (L.) R.Br.

PRIMULACEAE

Fairy candelabra	*Androsace septentrionalis* L.
Tufted loosestrife	*Lysimachia thyrsiflora* L.
Star-flower	*Trientalis borealis* Raf.

PYROLACEAE

Prince's pine	*Chimaphila umbellata* (L.) Bart. Var. *occidentalis* (Rydb.) Blake
One-flowered wintergreen	*Moneses uniflora* (L.) A. Gray
Common pink wintergreen	*Pyrola asarifolia* Michx.
Arctic wintergreen	*P. grandiflora* Radius
One-sided wintergreen	*P. secunda* L.

PINACEAE

Balsam fir	*Abies balsamea* (L.) Mill.
Ground juniper	*Juniperus communis* L. Var. *depressa* Pursh
Creeping juniper	*J. horizontalis* Moench
Tamarack	*Larix laricina* (DuRoi) K. Koch
White spruce	*Picea glauca* (Moench) Voss
Black spruce	*P. mariana* (Mill.) B.S.P.
Jack pine	*Pinus banksiana* Lamb.

RANUNCULACEAE

Red and white baneberry	_Actaea_ _rubra_ (Ait.) Willd.
Canada anemone	_Anemone_ _canadensis_ L.
Prairie anemone	_A._ _patens_ L. Var. _wolfgangiana_ (Bess.) Koch
Tall blue columbine	_Aquilegia_ _brevistyla_ Hook.
White water crowfoot	_Ranunculus_ _aquatilis_ L. Var. _capillaceus_ (Thuill.) D.C.
Seaside crowfoot	_R._ _cymbalaria_ Pursh
Yellow water crowfoot	_R._ _gmelinii_ D.C.
Macoun's buttercup	_R._ _macounii_ Britt.
Northern buttercup	_R._ _pedatifidus_ Smith Var. _affinus_ (R.Br.) L. Benson
Creeping buttercup	_R._ _repens_ L.
Cursed crowfoot	_R._ _sceleratus_ L.

ROSACEAE

Saskatoon berry	_Amelanchier_ _alnifolia_ Nutt.
Woodland strawberry	_Fragaria_ _vesca_ L. Var. _americana_ Porter
Wild strawberry	_F._ _virginiana_ Duchesne (_F._ _glauca_ Rydb.)
Yellow avens	_Geum_ _allepicum_ Jacq.
Yellow avens	_G._ _perincisum_ Rydb.
Silverweed	_Potentilla_ _anserina_ L.
White cinquefoil	_P._ _arguta_ Pursh
	_P._ _multifida_ L.
Alpine cinquefoil	_P._ _nivea_ L.
Rough cinquefoil	_P._ _norvegica_ L.
Marsh cinquefoil	_P._ _palustris_ (L.) Scop.
Pennsylvanian cinquefoil	_P._ _pensylvanica_ L.
Prickly rose	_Rosa_ _acicularis_ Lindl.
Common wild rose	_R._ _woodsii_ Lindl.
Cloudberry	_Rubus_ _chamaemorus_ L.
Wild red raspberry	_R._ _idaeus_ L. Var. _aculeatissimus_ Regel & Tiling
Trailing raspberry	_R._ _pubescens_ Raf.
Wild red raspberry	_R._ _strigosus_ Michx.

SALICACEAE

Balsam poplar	_Populus_ _balsamifera_ L.
Aspen poplar	_P._ _tremuloides_ Michx.
Beaked willow	_Salix_ _bebbiana_ Sarg.
Pussy willow	_S._ _discolor_ Muhl.
Sandbar willow	_S._ _interior_ Rowlee
	_S._ _lasiandra_ Benth.
Yellow willow	_S._ _lutea_ Nutt.
Glaucous bog willow	_S._ _pedicellaris_ Pursh

	S. petiolaris J.E. Sm.
	S. planifolia Pursh
Balsam willow	*S. pyrifolia* Anderss.
	S. rigida Muhl.
	S. scouleriana Barratt
Autumn willow	*S. serissima* (Bailey) Fern.
SANTALACEAE	
Comandra	*Comandra umbellata* (L.) Nutt. Var. *pallida* (A.D.C.) M.E. Jones
Bastard toad-flax	*Geocaulon lividum* (Richards.) Fern.
SAXIFRAGACEAE	
Alum root	*Heuchera richardsonii* R.Br.
Mitrewort	*Mitella nuda* L.
Wild black currant	*Ribes hudsonianum* Richards.
Wild gooseberry	*R. oxyacanthoides* L.
Saxifrage	*Saxifraga tricuspidata* Rottb.
SCROPHULARIACEAE	
Mudwort	*Limosella aquatica* L.
Speedwell	*Veronica peregrina* L. Var. *xalapensis* (H.B.K.) St. John & Warren
SPARGANIACEAE	
Giant bur-reed	*Sparganium eurycarpum* Engelm.
Slender bur-reed	*S. minimum* (Hartm.) Fries
TYPHACEAE	
Common cattail	*Typha latifolia* L.
UMBELLIFERAE	
Water hemlock	*Cicuta maculata* L. Var. *angustifolia* Hook.
Cow parsnip	*Heracleum lanatum* Michx.
Water parsnip	*Sium suave* Walt.
URTICACEAE	
Common nettle	*Urtica gracilis* Ait.

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Moss, E. H. 1959. Flora of Alberta. London: Oxford University Press. Printed in the Netherlands.

Cormack, R. G. H. 1967. Wild Flowers of Alberta. Department of Industry and Development, Government of Alberta. The Queen's Printer, Edmonton, 415 p.

SECTION B

A CHECKLIST OF THE FISHES OF THE PEACE-ATHABASCA DELTA REGION

by

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Of the 47 species of fish indigenous to the Province of Alberta, 18 are found in the area described as the Delta region. Although several salmonid fishes, i.e., rainbow trout, brook trout and splake have been introduced into lakes in Wood Buffalo National Park, these lakes are isolated bodies of water which do not have surface drainage connections with waters of the Delta area. Also, there is no evidence of any of the non-indigenous salmonids introduced in headwater areas of the Peace or Athabasca systems having found their way to the Delta portions of these systems. The following list of species present in the area therefore represents those fishes which naturally invaded the area after the retreat of the Keewatin ice sheet.

SALMONIDAE

Shallow water cisco	*Coregonus artedii* LeSueur
Lake whitefish	*Coregonus clupeaformis* Mitchill
Short jaw cisco	*Coregonus zenithicus* Jordan and Evermann
Lake trout	*Salvelinus namaycush* Walbaum
Arctic grayling	*Thymallus arcticus* Pallas

ESOCIDAE

Northern pike	*Esox lucius* Linnaeus

HIODONTIDAE

Goldeye	*Hiodon alosoides* Rafinesque

CYPRINIDAE

Emerald shiner	*Notropis atherinoides* Rafinesque
Spottail shiner	*Notropis hudsonius* Clinton
Flathead chub	*Platygobio gracilis* Richardson

CATOSTOMIDAE

Longnose sucker	*Catostomus catostomus* Forster
White sucker	*Catostomus commersoni* Lacepede

GADIDAE

Burbot (ling, maria)	_Lota lota_ Linnaeus

PERCOPSIDAE

Trout-perch	_Percopsis omiscomaycus_ Walbaum

GASTEROSTEIDAE

Brook stickleback	_Culaea inconstans_ Kirtland
Ninespine stickleback	_Pungitius pungitius_ Linnaeus

PERCIDAE

Walleye	_Stizostedion vitreum vitreum_ Mitchill

COTTIDAE

Slimy sculpin	_Cottus cognatus_ Richardson

REFERENCES

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Rawson, D. S. 1947. Lake Athabasca, North West Canadian Fisheries Surveys in 1944-45. Fish. Res. Bd. Canada. Bull. 72: 69-85.

SECTION C

THE BIRDS OF THE PEACE-ATHABASCA DELTA AND OF THE LAKE ATHABASCA REGION

by

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INTRODUCTION

In connection with the tabular account presented below, I would explain that my field work has been concentrated in the portion of northeastern Alberta east of Wood Buffalo Park and thus east of the Delta. Information about the birds of the Delta has therefore been obtained from the literature and from unpublished records made by Mr. T. M. Shortt of the Royal Ontario Museum and by Prof. W. R. Salt of the University of Alberta.

While the Delta is a well-defined region, the decision as to the limits of the Lake Athabasca region, which for the purposes of the table below, excludes the Delta, was more arbitrary and was influenced by the avifaunal publications available. As shown in Fig. 1, it includes all of Wood Buffalo Park (except the Delta), the northeastern corner of Alberta, and a zone around the shores of Lake Athabasca eastward as far as a point between Stony Rapids and Black Lake, Saskatchewan.

For a description of this area, the reader is referred to Soper's account (p. 20-27, Soper, 1942) of Wood Buffalo Park and Nero's account of Lake Athabasca (p. 12-23, Nero, 1963).

As the English bird names used in the table are those of the American Ornithologist's Union "Check-list of North American Birds," fifth edition, 1957, and as this and a number of recent bird guides give these names along with the accepted scientific names, the latter have been omitted in the table below. An asterisk following a bird name indicates that a specimen has been collected within the Lake Athabasca region, in this case

including the Delta. As to the terms used in the table: "migrant" indicates that the species in question only passes through the area on migration; "resident" that it is to be found in the area at all times of the year; "summer resident" that it is only present during the summer half of the year; "breeds" indicates that there are specific breeding records for the area; "local" indicates a patchy rather than a general distribution; a dash indicates that the species is not found in the area in question; while no entry merely indicates that there is insufficient information to indicate its status.

ORNITHOLOGICAL WORK IN THE AREA

The major facts about work by others published or unpublished are given in the annotated list of references. It should be added, however, that F. Harper, in addition to his 1914 journey described in his thesis of 1925, also worked on Lake Athabasca in 1920. His 1920 findings have not been published, but Nero was able to see those made in Saskatchewan and Nero's publications (1963 and 1967a) cite those of Harper's records he deemed noteworthy.

My own travels in the area can be summarized as follows:

1969 - Based at Chipewyan, June 2-6, boat journey to Fiddler Point where camped on the 3rd, return to Chipewyan next day. June 5 by boat to Poplar Island off old Fort Point.

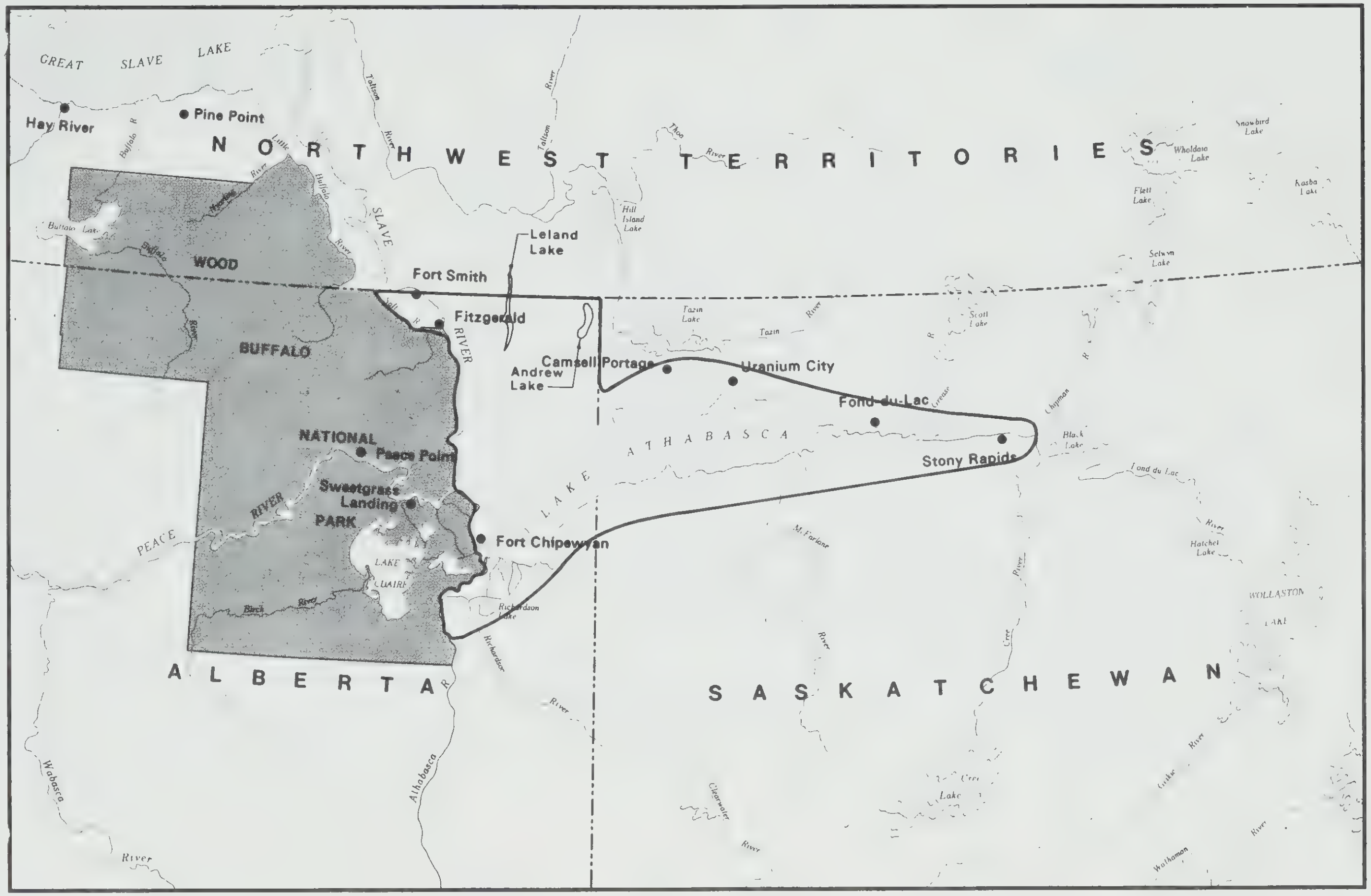


Fig.I Boundary of Lake Athabasca region.

1970 - January 27-30, stay at Eldorado, Saskatchewan, with drives to Uranium City and Bushell. July 10-14, camped at Andrew Lake, Alberta.

1971 - June 22 and 23, based at Eldorado, camped on Lillabo Lake on the Alberta-Saskatchewan border south of Lake Athabasca. June 24 walked to south shore of Lake Athabasca. June 25 and 26 followed lake shore west as far as Stone Point, then back to a few miles east of Point Brule. July 2 and 3 by boat from Bushell west as far as Bustard Island with stops at various islands and islets en route. July 5-8, camped at Leland Lake, Alberta.

1972 - March 9-13, stayed at Chipewyan with local walks and drives to "Sweet Grass" near the Peace River and the "Dog Camp" west of Chipewyan.

ZOOGEOGRAPHICAL COMMENTS ON THE BIRD LIFE

The floras and faunas over broad land zones, which are basically climatically conditioned, show great overall similarity within a zone, and contrasts with adjacent zones. Due allowance has to be made for small-scale local diversity due to different habitats, of which there may be several up to many in any zone. The concept of life zones as applied particularly to North America is due to C. H. Merriam (1893), and a general account of this topic as applied to Canada only is given by Anderson (1937). Some writers consider that a concept of biological communities is more appropriate. The writer, like Nero in his publication on the area under discussion, prefers to use the older system; but

the relationship between the two systems as applied to the area in question can be tabulated as follows:

Community or Ecotone (Ecotones are broad areas of overlap between two communities which may have a few distinctive species of their own)	Life Zone
Tundra	Arctic
Tundra-coniferous forest ecotone	Hudsonian
Coniferous forest	Canadian

The Lake Athabasca region as here defined lies entirely in the Canadian Zone; but in life zone maps published as recently as Anderson's (1937), the border between the Canadian and Hudsonian Zones is drawn at a slant from the northwest to the southeast across Lake Athabasca between its western one-third and its eastern two-thirds, i.e., much of the eastern part of our area was then considered to lie in the Hudsonian Zone. As this zone has no distinctive mammal species, its recognition depends mainly on key elements of the breeding bird fauna, characteristic species being the tree and Harris' sparrow and the gray-cheeked thrush. Due to the well-known recent climatic amelioration of the boreal region, life zone boundaries have now shifted so that the Canadian Hudsonian boundary in the area under discussion runs at the same slant as before but across the eastern corner of northern Saskatchewan (see map, p. 6 in Nero, 1967a), and thus beyond the Lake Athabasca area. Nevertheless, as Harper (1931) pointed out, there was evidence (much of it now changed due to climatic amelioration since he worked there) that a relatively higher-lying area (see sketch Fig. 2) which he called the Tazin Highlands, extending from the north shore of

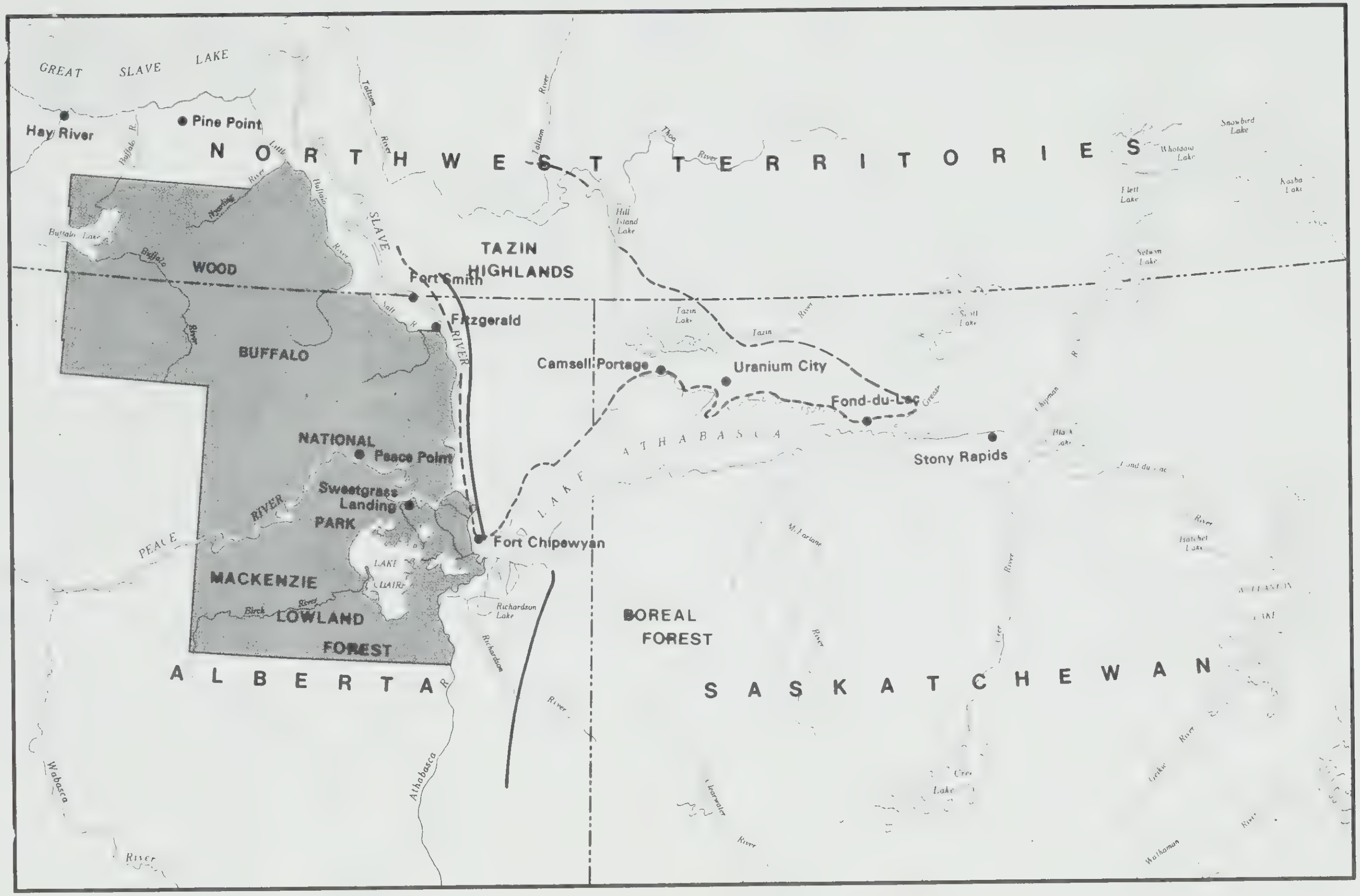


Fig. 2 Boundary between Mackenzie Lowland Forest and Boreal Forest, with edge of Tazin Highlands indicated by dotted line.

Lake Athabasca towards Great Slave Lake, partly in Alberta, partly in Saskatchewan, and also in the N.W.T., represented a fairly distinct faunal area characterized by a mixture of Canadian and Hudsonian elements. The climatic amelioration already mentioned has since allowed certain Canadian Zone bird species which he found absent there to invade it successfully; but even now there is something distinctive about this area in such features as the absence of the red-tailed hawk and, once one is well within it, of the white-throated sparrow. Future work is likely to add further distinctions between the Tazin Highlands and more evidently Canadian Zone areas to the west and south such as the Slave River lowlands, the Athabasca Delta, and the generally low-lying land south of the Alberta portion of Lake Athabasca.

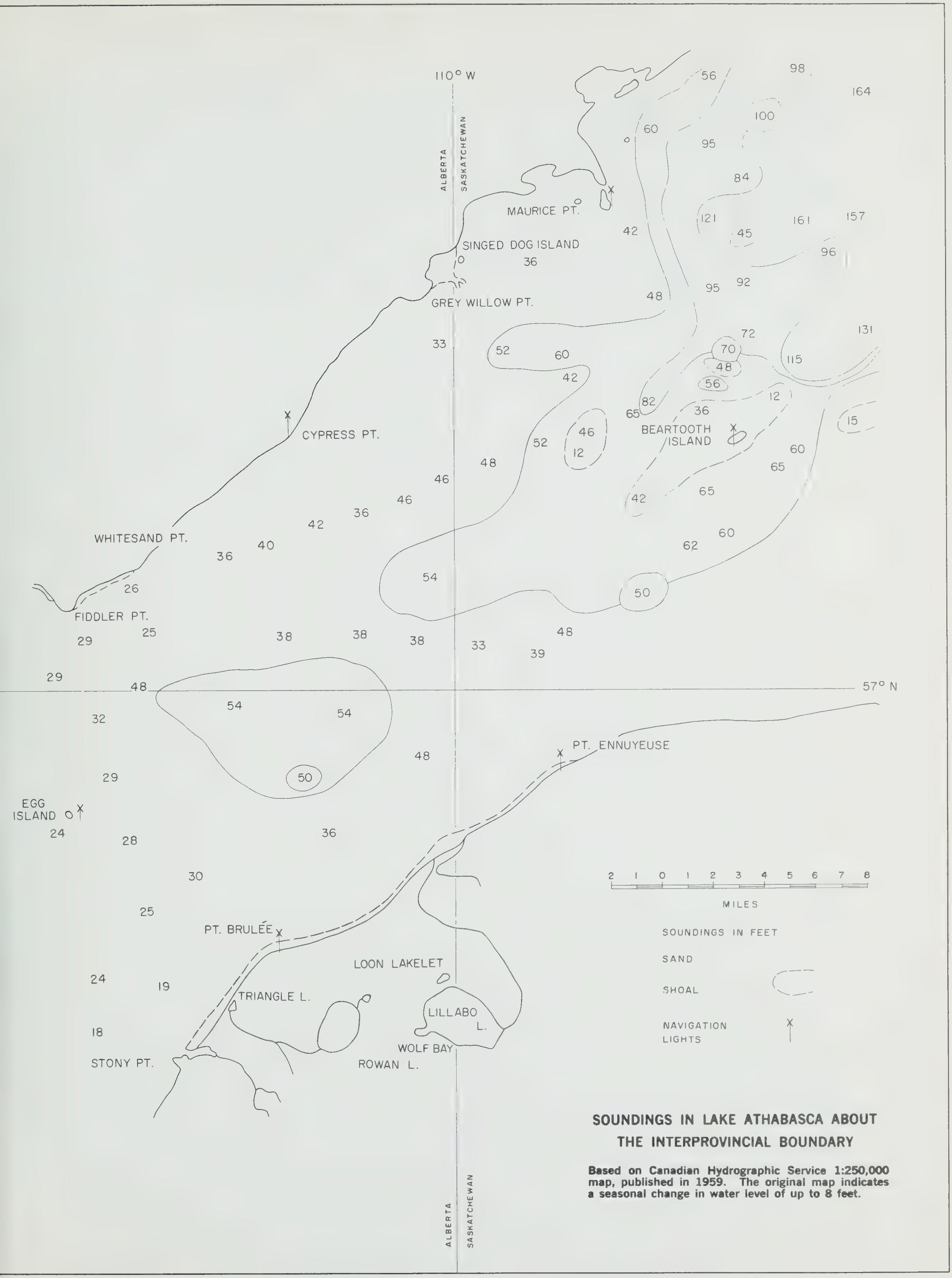
Although the whole region is now in the Canadian Life Zone, there are still certain broad differences between the avifauna of its western and its eastern portion. In the west is the Mackenzie lowland forest, mainly on lowland alluvial sand, and to the east, the boreal forest on the Precambrian Shield; there is also a climatic difference, the east being colder than the west and the dividing line following roughly the same line as the border between the features named (Fig. 2). A number of birds are summer residents and breed or probably breed in the western area and are either altogether absent or much scarcer in the eastern portion. They are: blue-winged teal, canvasback, ruddy duck, sora rail, least flycatcher, house and winter wren, starling, red-eyed and warbling vireo, black-throated green

warbler, ovenbird, northern waterthrush, mourning warbler, yellowthroat, Canada warbler, redstart, and the rose-breasted grosbeak.

Another east-west difference, the line of demarcation this time following the Alberta-Saskatchewan border, is shown by the Arctic tern. Apart from within an area well south of Lake Athabasca (Nero, 1963), this bird breeds freely on many islands in the Saskatchewan portion of the Lake as close to the interprovincial border as islets off Grey Willow Point; but, as my examination of most likely islands in the Alberta portion of the Lake in 1971 showed, it does not nest in Alberta. As Fig. 3 shows, this part of the Lake is generally shallower than the Alberta portion; it is also more muddy due to the inflow of the Athabasca and at times the Peace River. These features may affect the available food supply in a way that is important to Arctic but not common terns, for the latter breed over the whole Lake.

THE DELTA

The Peace-Athabasca Delta forms the northern limit of breeding of the redhead, Franklin's gull, long-billed marsh wren, and the yellow-headed blackbird. While it is of great importance as a waterfowl staging area and of considerable importance as a waterfowl breeding area, it is of less importance to shorebirds. Most species only pass through it as migrants and not in very large numbers. The most common breeding shorebird, the common sandpiper, breeds along rivers and water channels and would thus


110° W
57° N
ALBERTA
SASKATCHEWAN
MAURICE PT.
SINGED DOG ISLAND
GREY WILLOW PT.
CYPRESS PT.
WHITESAND PT.
FIDDLER PT.
BEARTOOTH ISLAND
PT. ENNUYEUSE
EGG ISLAND
PT. BRULÉE
LOON LAKELET
TRIANGLE L.
LILLABO L.
WOLF BAY
ROWAN L.
STONY PT.
2 1 0 1 2 3 4 5 6 7 8
MILES
SOUNDINGS IN FEET
SAND
SHOAL
NAVIGATION LIGHTS
SOUNDINGS IN LAKE ATHABASCA ABOUT THE INTERPROVINCIAL BOUNDARY
Based on Canadian Hydrographic Service 1:250,000 map, published in 1959. The original map indicates a seasonal change in water level of up to 8 feet.

~~Fig. 1~~ Fig. 3

be little affected by changing water levels. Apart from waterfowl, the species which are adversely affected by low water levels are marsh breeding species like the bittern, rail and the coot, the common snipe and lesser yellowlegs, marsh wren, Franklin's gull, black tern, and yellow-headed blackbird.

	PEACE-ATHABASCA DELTA	LAKE ATHABASCA REGION
Order Gaviiformes		
Family Gaviidae, Loons		
Common Loon*	fairly common migrant	fairly common summer resident, breeds
Yellow-billed Loon*		rare migrant, one record Saskatchewan
Arctic Loon*	rare migrant	rare summer resident, breeds Alberta
Red-throated Loon*	rare migrant	rare summer resident, breeds Saskatchewan
Order Podicipediformes		
Family Podicipedidae, Grebes		
Red-necked Grebe*	fairly common summer resident, breeds	fairly common summer resident, breeds
Horned Grebe*	fairly common summer resident, breeds	fairly common summer resident, breeds
Eared Grebe*	summer resident, breeds	
Pied-billed Grebe*	fairly common summer resident, breeds	fairly common summer resident, breeds along Slave River valley but east of there only to south shore of Lake Athabasca
Order Pelecaniformes		
Family Pelecanidae, Pelicans		
White Pelican*	rare migrant	summer resident, one breeding colony, only Alberta, elsewhere rare migrant

	PEACE-ATHABASCA DELTA	LAKE ATHABASCA REGION
Order Anseriformes		
Family Anatidae, Waterfowl		
Whistling Swan	regular migrant	rare migrant
Canada Goose*	migrant and summer resident, breeds	fairly common summer resident, breeds
White-fronted Goose	regular migrant	
Lesser Snow Goose	regular common migrant	migrant, Slave River Valley
Ross' Goose*	regular migrant	fairly common migrant
Mallard*	abundant summer resident, breeds	common summer resident, breeds
Black Duck*	rare vagrant	one sighting Saskatchewan
Gadwall*	fairly common summer resident, breeds	rare summer resident, probably breeds
Pintail*	migrant and common summer resident, breeds	fairly common summer resident, breeds
Baldpate*	migrant and fairly common summer resident, breeds	fairly common summer resident, breeds
Green-winged Teal*	fairly common summer resident, breeds	fairly common summer resident, breeds
Blue-winged Teal	fairly common summer resident, breeds	rare Slave River Valley, unknown further east
Shoveler	common summer resident, breeds	fairly rare summer resident, probably breeds
Redhead*	local summer resident, breeds	-------------

	PEACE-ATHABASCA DELTA	LAKE ATHABASCA REGION
Ring-necked Duck*	common summer resident, breeds	fairly common summer resident, breeds
Canvasback*	fairly common summer resident, breeds	-----------
Lesser Scaup*	fairly common summer resident, breeds	fairly common summer resident, breeds
Common Goldeneye	common summer resident, breeds	common summer resident, Wood Buffalo Park; fairly rare further east, breeds
Bufflehead*	fairly common summer resident on the rivers, breeds	common summer resident, breeds
Oldsquaw		scarce migrant Alberta portion of Lake Athabasca, as yet no good records for Saskatchewan portion
White-winged Scoter	rare summer resident, breeds	fairly rare summer resident, probably breeds
Surf Scoter*	rare summer resident	fairly common summer resident, breeds Saskatchewan
Ruddy Duck	fairly common summer resident, breeds	rare summer resident, Wood Buffalo Park; absent further east
Hooded Merganser	very rare migrant, one record	rare migrant
Common Merganser*	fairly rare migrant	common summer resident, breeds Saskatchewan, probably breeds Alberta

	PEACE-ATHABASCA DELTA	LAKE ATHABASCA REGION
Red-breasted Merganser*	fairly rare migrant	common summer resident, breeds Saskatchewan, probably breeds Alberta. This and the preceding species are rare in Wood Buffalo Park
Order Falconiformes		
Family Accipitridae, Hawks and Eagles		
Goshawk*		rather rare resident, breeds
Sharp-shinned Hawk*		rather rare summer resident, breeds
Red-tailed Hawk*	summer resident, probably breeds	fairly rare summer resident, probably breeds
Swainson's Hawk*		rare vagrant, only one record
Broad-winged Hawk*	rare vagrant	rare vagrant
Rough-legged Hawk	regular migrant	regular migrant
Golden Eagle	rare migrant	very rare summer resident, one breeding record, Saskatchewan
Bald Eagle	regular migrant, some breeding	fairly common summer resident, breeds
Marsh Hawk	fairly common summer resident, probably breeds	fairly common summer resident, probably breeds Peace-Athabasca and Slave River lowlands, rare or absent elsewhere
Family Pandionidae, Ospreys		
Osprey*	rare migrant	rare summer resident, one breeding record Saskatchewan

	PEACE-ATHABASCA DELTA	LAKE ATHABASCA REGION
Family Falconidae, Falcons		
Gyrfalcon	rare winter visitor	rare winter visitor
Peregrine Falcon*	scarce summer resident, breeds	scarce summer resident in Alberta, breeds, no records for Saskatchewan part of region
Merlin (Pigeon Hawk)		fairly rare resident, breeds
Sparrow Hawk*	common summer resident, probably breeds	common summer resident, breeds
Order Galliformes		
Family Tetraonidae, Grouse and Ptarmigans		
Spruce Grouse*	common resident, probably breeds	common resident, breeds
Ruffed Grouse*	common resident, probably breeds	common resident, breeds Wood Buffalo Park but rare or absent further east
Willow Ptarmigan*	common winter visitor	common winter visitor
Rock Ptarmigan*		rare winter visitor, Saskatchewan only
Sharp-tailed Grouse*	common resident, probably breeds	fairly common Wood Buffalo Park, only local further east, breeds
Order Ciconiiformes		
Family Ardeidae, Herons and Bitterns		
Great Blue Heron	rare vagrant	

	PEACE-ATHABASCA DELTA	LAKE ATHABASCA REGION
American Bittern*	common summer resident, probably breeds	fairly common summer resident, breeds
Order Gruiformes		
Family Gruidae, Cranes		
Whooping Crane	very rare migrant	local summer resident Wood Buffalo Park, breeds, elsewhere very rare migrant
Sandhill Crane	migrant	local summer resident
Family Rallidae, Rails and Coots		
Virginia Rail*		a male in breeding condition collected at Chipewyan is the only record
Sora Rail*	common summer resident, breeds	common summer resident Slave River lowlands, uncommon further east, probably breeds
Yellow Rail*	rare summer resident, probably breeds	rare summer resident Wood Buffalo Park, may breed but unknown further east
Coot*	fairly common summer resident, breeds	summer resident Wood Buffalo Park and further east as far north as south shore of Lake Athabasca, breeds
Order Charadriiformes		
Family Recurvirostridae, Avocets		
American Avocet*		very rare vagrant, two collected late 19th century at Chipewyan

	PEACE-ATHABASCA DELTA	LAKE ATHABASCA REGION
Family *Charadriidae*, Plovers and Turnstones		
Semipalmated Plover*	regular migrant	fairly common migrant, summer resident, breeds sand dune area on south shore of Lake Athabasca, Saskatchewan
Killdeer*	common summer resident, breeds	fairly common summer resident, breeds, probably absent in Tazin Highlands
American Golden Plover*	regular migrant	migrant along Slave River, no records further east
Black-bellied Plover*	regular migrant	migrant as far east as Sand Point east of Ft. Chipewyan
Ruddy Turnstone*	migrant	migrant Chipewyan area, one record, Poplar Point, Lake Athabasca, Saskatchewan
Family *Scolopacidae*, Snipes and Sandpipers		
Common Snipe*	common summer resident, breeds	fairly rare summer resident, breeds, one sight record, Saskatchewan
Whimbrel		one sight record, Saskatchewan
Upland Plover*		rare summer resident between Hay Camp, Wood Buffalo Park and Ft. Smith, probably breeds there, absent elsewhere
Spotted Sandpiper*	common summer resident, breeds	common summer resident of the whole region, breeds

	PEACE-ATHABASCA DELTA	LAKE ATHABASCA REGION
Solitary Sandpiper*	fairly rare summer resident, probably breeds	fairly rare summer resident, probably breeds
Greater Yellowlegs*	regular migrant	no records for Wood Buffalo Park but fairly common though local summer resident further east, breeds
Lesser Yellowlegs*	common summer resident, probably breeds	fairly common summer resident breeds
Knot		rare migrant, Sand Point east of Chipewyan and two probable sightings, Lake Athabasca, Saskatchewan
Pectoral Sandpiper*	regular migrant	fairly rare migrant
White-rumped Sandpiper*	fairly rare migrant	fairly common migrant
Baird's Sandpiper*	regular migrant	fairly common migrant
Least Sandpiper*	common migrant	fairly common migrant and local summer visitor, possibly breeds
Dunlin*		rare migrant, one collected, Lake Athabasca, Saskatchewan
Short-billed Dowitcher*		rare migrant Wood Buffalo only
Long-billed Dowitcher*		one record, Lake Athabasca, Saskatchewan
Stilt Sandpiper*	migrant, sometimes in large numbers	fairly rare migrant
Semipalmated Sandpiper*	migrant	fairly common migrant

	PEACE-ATHABASCA DELTA	LAKE ATHABASCA REGION
Buff-breasted Sandpiper*	migrant	scarce, migrant Wood Buffalo Park, no records further east
Sanderling*		fairly rare migrant
Family *Phalaropodidae*, Phalaropes		
Wilson's Phalarope*	rare summer visitant, possibly breeds	
Northern Phalarope*		fairly rare migrant and very rare summer resident, has bred Saskatchewan
Family *Stercorariidae*, Jaegers		
Pomarine Jaeger	very rare migrant	very rare migrant
Parasitic Jaeger*		migrant and fairly rare summer visitant
Long-tailed Jaeger	one sight record of a migrant	
Family *Laridae*, Gulls and Terns		
Glaucous Gull*		very rare migrant, Saskatchewan
Thayer's Gull*		very rare migrant, Saskatchewan
Herring Gull*	fairly common summer visitant	common summer resident, breeds islands on Lake Athabasca, Alberta and Saskatchewan
California Gull*	fairly common summer visitant	common summer resident, breeds islands on Lake Athabasca, Alberta and Saskatchewan

	PEACE-ATHABASCA DELTA	LAKE ATHABASCA REGION
Ring-billed Gull*	fairly common summer visitant	fairly common summer resident, breeds
Mew Gull*	fairly common summer visitant	common summer resident, breeds Saskatchewan, almost certainly also Alberta but no proof
Franklin's Gull*	common summer resident, breeds, most northern breeding colony in Canada	fairly common in areas, e.g. Chipewyan close to the Delta, rare elsewhere
Bonaparte's Gull*	fairly common summer visitant	fairly common summer resident, breeds Saskatchewan and probably Alberta
Little Gull*		rare visitant, one Saskatchewan record
Sabine's Gull*		rare migrant, one record each for Alberta and Saskatchewan
Common Tern*	common summer visitant	common summer resident, breeds islands, Lake Athabasca, Alberta and Saskatchewan
Arctic Tern*	fairly rare migrant	common summer resident, breeds Saskatchewan but only visitant and migrant in Alberta
Caspian Tern*	fairly rare summer visitant	summer resident, breeds, one Alberta colony, elsewhere only fairly rare summer visitant
Black Tern*	common summer resident, breeds	rare summer resident, breeds, probably only as far as south shore of Lake Athabasca

	PEACE-ATHABASCA DELTA	LAKE ATHABASCA REGION
Order Columbiformes		
Family Columbidae, Pigeons and Doves		
Mourning Dove		vagrant, one Alberta and several records for one Saskatchewan locality
Order Strigiformes		
Family Strigidae, Typical Owls		
Great Horned Owl*		fairly common resident, breeds
Snowy Owl	uncommon winter visitor	uncommon winter visitor
Hawk-Owl*	rare summer resident	fairly common resident, breeds
Barred Owl		very rare resident, Saskatchewan one record only
Great Gray Owl*	rare summer resident	fairly rare resident, breeds
Long-eared Owl*		rare visitant
Short-eared Owl*	fairly common summer resident, probably breeds	uncommon Wood Buffalo Park, no definite records further east
Boreal Owl*		rare resident, breeds
Order Caprimulgiformes		
Family Caprimulgidae, Goatsuckers		
Common Nighthawk*	common summer resident, probably breeds	common summer resident, breeds

	PEACE-ATHABASCA DELTA	LAKE ATHABASCA REGION
Order Apodiformes		
Family Trochilidae, Hummingbirds		
Ruby-throated Hummingbird	rare summer visitant	rare summer visitant, Chipewyan only
Order Coraciiformes		
Family Alcedinidae, Kingfishers		
Belted Kingfisher*	fairly common summer resident, probably breeds	fairly common summer resident, breeds
Order Piciformes		
Family Picidae, Woodpeckers		
Yellow-shafted Flicker*	common summer resident, breeds	common summer resident, breeds
Pileated Woodpecker		uncommon resident, breeds
Yellow-bellied Sapsucker*	common summer resident, breeds	fairly common summer resident, breeds
Hairy Woodpecker*	common resident, probably breeds	fairly common resident, probably breeds
Downy Woodpecker*	fairly common resident, probably breeds	fairly common resident, probably breeds
Black-backed Three-Toed Woodpecker*		uncommon resident, breeds
Northern Three-toed Woodpecker*		uncommon resident, probably breeds

	PEACE-ATHABASCA DELTA	LAKE ATHABASCA REGION
Order Passeriformes		
Family Tyrannidae, Tyrant Flycatchers		
Eastern Kingbird*	common summer resident, breeds	fairly common summer resident, breeds
Scissor-tailed Flycatcher		vagrant, one record Chipewyan
Eastern Phoebe*	common summer resident, breeds	fairly common summer resident, breeds
Yellow-bellied Flycatcher*	rare summer resident	rare summer resident, probably breeds
Traill's Flycatcher*	fairly common summer resident, probably breeds	fairly common summer resident, probably breeds
Least Flycatcher*	common summer resident, probably breeds	common in western, uncommon in eastern part, summer resident, breeds
Western Wood Pewee*	rare summer resident, probably breeds	rare summer resident, probably breeds
Olive-sided Flycatcher*		fairly common summer resident, probably breeds
Family Alaudidae, Larks		
Horned Lark*	migrant	migrant and local summer resident, breeds in sand dunes south of Lake Athabasca
Family Hirundinidae, Swallows		
Tree Swallow*	fairly common summer resident, breeds	common summer resident, breeds

	PEACE-ATHABASCA DELTA	LAKE ATHABASCA REGION
Bank Swallow*	fairly common summer resident, probably breeds	uncommon summer resident, breeds
Barn Swallow*	fairly common summer resident, probably breeds	common summer resident, breeds
Cliff Swallow*	fairly common summer resident, probably breeds	uncommon summer resident, breeds
Family _Corvidae_, Jays, Magpies, and Crows		
Gray Jay*	fairly common resident, probably breeds	common resident, breeds
Black-billed Magpie*	rare visitant	rare visitant
Common Raven*	common resident, probably breeds	common resident, breeds
Common Crow*	common summer resident, breeds	fairly common summer resident, breeds
Family _Paridae_, Chickadees		
Black-capped Chickadee*	common resident, probably breeds	fairly common resident, breeds
Boreal Chickadee	fairly common resident, probably breeds	common resident, breeds
Family _Sittidae_, Nuthatches		
Red-breasted Nuthatch*		fairly common summer resident, breeds

	PEACE-ATHABASCA DELTA	LAKE ATHABASCA REGION
Family *Troglodytidae*, Wrens		
House Wren	summer resident, probably breeds	summer resident, probably breeds Wood Buffalo Park but not further east
Winter Wren		rare summer resident, probably breeds Wood Buffalo Park, absent further east
Long-billed Marsh Wren*	fairly common summer resident, probably breeds	
Rock Wren		vagrant, one sighting Chipewyan
Family *Turdidae*, Thrushes		
Robin*	common summer resident, probably breeds	fairly common summer resident, breeds
Hermit Thrush*		fairly common summer resident, breeds
Swainson's Thrush*		fairly common summer resident, breeds
Gray-cheeked Thrush*		uncommon migrant
Mountain Bluebird*		rare summer visitant, possibly breeds
Family *Sylviidae*, Kinglets		
Golden-crowned Kinglet*		rare summer visitant, probably breeds Alberta, no Saskatchewan records
Ruby-crowned Kinglet*	summer visitor, probably breeds	common summer resident, breeds

	PEACE-ATHABASCA DELTA	LAKE ATHABASCA REGION
Family Motacillidae, Pipits		
Water Pipit*	fairly common migrant	uncommon migrant
Family Bombycillidae, Waxwings		
Bohemian Waxwing	resident, probably breeds	fairly common resident, breeds
Cedar Waxwing		uncommon summer resident, breeds
Family Sturnidae, Starlings		
Starling	uncommon summer visitant	uncommon summer resident, breeds Alberta, no Saskatchewan records as yet
Family Vireonidae, Vireos		
Solitary Vireo*	uncommon summer resident, probably breeds	uncommon summer resident, probably breeds
Red-eyed Vireo*	common summer resident, probably breeds	common Alberta, uncommon Saskatchewan summer resident, probably breeds
Philadelphia Vireo*	summer visitant	uncommon summer resident, probably breeds
Warbling Vireo*	common summer resident, probably breeds	fairly common summer resident Wood Buffalo Park, probably breeds, absent further east
Family Parulidae, Wood Warblers		
Black-and-white Warbler*		fairly common summer resident Wood Buffalo Park and Chipewyan, probably breeds, none further east

	PEACE-ATHABASCA DELTA	LAKE ATHABASCA REGION
Tennessee Warbler*	common summer resident, probably breeds	common summer resident, breeds
Orange-crowned Warbler*		local summer resident, probably breeds
Yellow Warbler*	common summer resident, breeds	common summer resident, breeds
Magnolia Warbler	local summer resident, probably breeds	local summer resident, breeds
Cape May Warbler*		local to rare summer resident, probably breeds
Myrtle Warbler	fairly common migrant	fairly common summer resident, breeds
Black-throated Green Warbler*	local summer resident, probably breeds	only summer records for upper Slave River Valley, absent elsewhere
Bay-breasted Warbler*		fairly rare summer resident, probably breeds
Blackpoll Warbler*	fairly rare summer resident, may breed	fairly rare summer resident, breeds
Palm Warbler*		fairly common summer resident, breeds
Ovenbird*	common summer resident, probably breeds	fairly common Slave River lowlands where it probably breeds, absent further east
Northern Waterthrush*	common summer resident, probably breeds	summer resident, common Wood Buffalo Park, uncommon further east, probably breeds

	PEACE-ATHABASCA DELTA	LAKE ATHABASCA REGION
Mourning Warbler*	rare summer resident, probably breeds	summer resident, probably breeds, Chipewyan, absent elsewhere
Yellowthroat	fairly common summer resident, probably breeds	summer resident, probably breeds, southern half of Wood Buffalo Park and Chipewyan, none further east
Wilson's Warbler*	local summer resident, breeds	uncommon summer resident, probably breeds
Canada Warbler	rare summer resident, probably breeds	
American Redstart	common summer resident, probably breeds	fairly common summer resident Wood Buffalo Park but not further east
Family <u>Ploceidae</u>, Weaver Finches		
House Sparrow	summer resident, may breed	resident in settlements east as far as Uranium City-Eldorado, probably breeds
Family <u>Icteridae</u>, Blackbirds		
Yellow-headed Blackbird*	local summer resident, breeds	
Red-winged Blackbird*	common summer resident, breeds	common summer resident, breeds
Rusty Blackbird	fairly common summer resident, probably breeds	fairly common summer resident, breeds
Common Grackle*	common summer resident, breeds	summer resident, common in western, uncommon in eastern part, probably breeds

	PEACE-ATHABASCA DELTA	LAKE ATHABASCA REGION
Brown-headed Cowbird	common summer resident, probably breeds	rare summer resident, probably breeds
Family _Thraupidae_, Tanagers		
Western Tanager*		fairly common summer resident Slave River lowlands and Chipewyan, rare elsewhere, probably breeds
Family _Fringillidae_, Finches, Sparrows, etc.		
Rose-breasted Grosbeak*	summer resident, probably breeds	summer resident, probably breeds Wood Buffalo Park and Chipewyan, absent further east
Evening Grosbeak*		rare summer visitor, may breed Wood Buffalo Park, elsewhere uncommon migrant
Pine Grosbeak*	rare migrant	rare resident, may breed
Hoary Redpoll*		fairly common winter visitor Alberta, rarer Saskatchewan
Common Redpoll*		uncommon resident, breeds
Pine Siskin	summer resident, may breed	fairly common summer resident, probably breeds
Red Crossbill*	summer visitant	fairly common summer resident, probably breeds
White-winged Crossbill*		fairly common summer resident, probably breeds
Savannah Sparrow*	common summer visitor, breeds	common west but uncommon east, summer visitor, breeds

	PEACE-ATHABASCA DELTA	LAKE ATHABASCA REGION
Le Conte's Sparrow	summer resident, probably breeds	local summer visitor, breeds
Sharp-tailed Sparrow*	summer resident, may breed	summer visitor, Slave River and Chipewyan only, may breed
Vesper Sparrow*		uncommon summer resident, probably breeds
Slate-colored Junco		common summer resident, breeds
Tree Sparrow*	migrant	fairly common migrant
Chipping Sparrow*		common summer resident, breeds
Clay-colored Sparrow	summer resident	uncommon summer resident, probably breeds
Harris' Sparrow		regular migrant
White-crowned Sparrow*		fairly common summer resident, breeds
White-throated Sparrow*	common summer resident, breeds	common summer resident, breeds
Fox Sparrow*	local summer resident, probably breeds	very local summer resident, probably breeds
Lincoln's Sparrow*	fairly common summer resident, probably breeds	fairly common summer resident, breeds
Swamp Sparrow*	common summer resident, probably breeds	fairly common summer resident, breeds
Song Sparrow	fairly common summer resident, probably breeds	fairly common summer resident, breeds

	PEACE-ATHABASCA DELTA	LAKE ATHABASCA REGION
Lapland Longspur*	fairly common migrant	regular migrant
Smith's Longspur*		rare migrant
Snow Bunting*	common migrant	common migrant and probably also winter visitor

ACKNOWLEDGEMENTS

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SECTION D

CHECKLIST OF THE MAMMALS OF THE PEACE-ATHABASCA DELTA

by

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CHECKLIST OF MAMMALS

The Peace-Athabasca Delta supports a wide variety of mammals. They range from the smallest living mammal - the pigmy shrew - to the largest land mammal in North America, the bison. Mammals are found in every plant community on the Delta. Muskrats and beaver inhabit the ponds and streams, mice and bison are found in the meadows, moose in the mixed woods, and squirrels in the conifers.

The following mammals are known or believed to be inhabitants of the Delta region. Scientific and common nomenclature are according to Hall and Kelson, *North American Mammals*, 1959.

SORICIDAE

masked shrew - *Sorex cinereus*

arctic shrew - *Sorex arcticus*

dusky shrew - *Sorex obscurus*

northern water shrew - *Sorex palustris*

pigmy shrew - *Microsorex hoyi*

VESPERTILIONIDAE

little brown bat - *Myotis lucifugus*

big brown bat - *Eptesicus fuscus*

hoary bat - *Lasiurus cinereus*

URSIDAE

black bear - *Ursus americanus*

PROCYONIDAE

raccoon - *Procyon lotor* - one trapped in 1930

MUSTELIDAE

marten - *Martes americana*

fisher - *Martes pennanti*

shorttail weasel - *Mustela erminea*

least weasel - *Mustela rixosa*

mink - *Mustela vison*

wolverine - *Gulo luscus*

otter - *Lutra canadensis*

striped skunk - *Mephitis mephitis*

CANIDAE

coyote - *Canis latrans*

timber wolf - *Canis lupus*

red fox - *Vulpes vulpes*

arctic fox - *Alopex lagopus*

FELIDAE

lynx - *Lynx canadensis*

SCIURIDAE

woodchuck - *Marmota monax*

least chipmunk - *Eutamias minimus*

red squirrel - *Tamiasciurus hudsonicus*

flying squirrel - *Glaucomys sabrinus*

CASTORIDAE

beaver - _Castor canadensis_

CRICETIDAE

white-footed mouse - _Peromyscus maniculatus_

northern bog lemming - _Synaptomys borealis_

mountain phenacomys - _Phenacomys intermedius_

boreal redback vole - _Clethrionomys gapperi_

meadow vole - _Microtus pennsylvanicus_

yellow-cheeked vole - _Microtus xanthognathus_

muskrat - _Ondatra zibethica_

ZAPODIDAE

meadow jumping mouse - _Zapus hudsonicus_

ERETHIZONTIDAE

porcupine - _Erethizon dorsatum_

LEPORIDAE

varying hare - _Lepus americanus_

CERVIDAE

mule deer - _Odocoileus hemionus_

moose - _Alces alces_

woodland caribou - _Rangifer tarandus sylvestris_

barrenground caribou - _Rangifer tarandus arcticus_

BOVIDAE

wood x plains bison hybrid - *Bison bison bison* x *Bison bison athabascae*

SECTION E

WALLEYES AND WATER LEVELS IN LAKE ATHABASCA

by

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INTRODUCTION

Walleyes, Stizostedion v. vitreum (Mitchill), have been traditionally harvested for human consumption and dog food by the native people of Lake Athabasca and the Athabasca River area. A commercial fishery for this species has operated in the Alberta portion of Lake Athabasca since 1943. In the spring of 1961, a commercial fisherman discovered walleyes concentrated in Richardson Lake, a shallow lake of 28 square miles located 20 miles south of and draining into Lake Athabasca through the Athabasca River Delta (Fig. 1). The following spring about 150,000 pounds of walleyes were netted in Richardson Lake and included with the commercial quota set for Lake Athabasca. In 1963, a commercial fishery that preceded the fishery in Lake Athabasca was approved for Richardson Lake.

Ecological studies on the walleyes in Richardson Lake were initiated in 1965 and continued to 1969. These investigations documented the cyclic movement of walleyes in the Richardson Lake complex, the Athabasca River Delta, and Lake Athabasca (Fig. 1). Mature walleyes were migrating into the Richardson Lake complex in the spring, spawning, and returning through the Athabasca River Delta and the shallow waters of Lake Athabasca to the oligotrophic, Saskatchewan waters of the lake. These fish were returning to the Richardson Lake complex the following spring to spawn. This movement of walleyes was a major contribution to three commercial fisheries: one in Richardson Lake, one in the Alberta waters of Lake Athabasca, and one in the Saskatchewan waters of the Lake (Table 1). As a result of

Table 1. Weight in pounds of walleye and northern pike commercially harvested from Richardson Lake and Lake Athabasca in Alberta and Lake Athabasca in Saskatchewan in nine consecutive years.

Year	Alberta Fishery				Saskatchewan Fishery	
	Richardson Lake		Lake Athabasca		Lake Athabasca	
	Walleye	N. Pike	Walleye	N. Pike	Walleye	N. Pike
1963	207,291	7,952	117,294	80,094	31,009	23,380
1964	137,672	19,377	214,769	171,696	31,642	45,904
1965	116,790	12,444	128,849	155,741	35,546	37,276
1966	60,147	19,360	135,590	170,801	14,851	26,963
1967	Closed		133,902	104,824	29,571	16,200
1968			212,424	281,971	62,039	53,351
1969			94,513	157,933	37,290	46,407
1970			37,652	40,013	135,994	92,035
1971			53,365	18,385	92,139	56,568

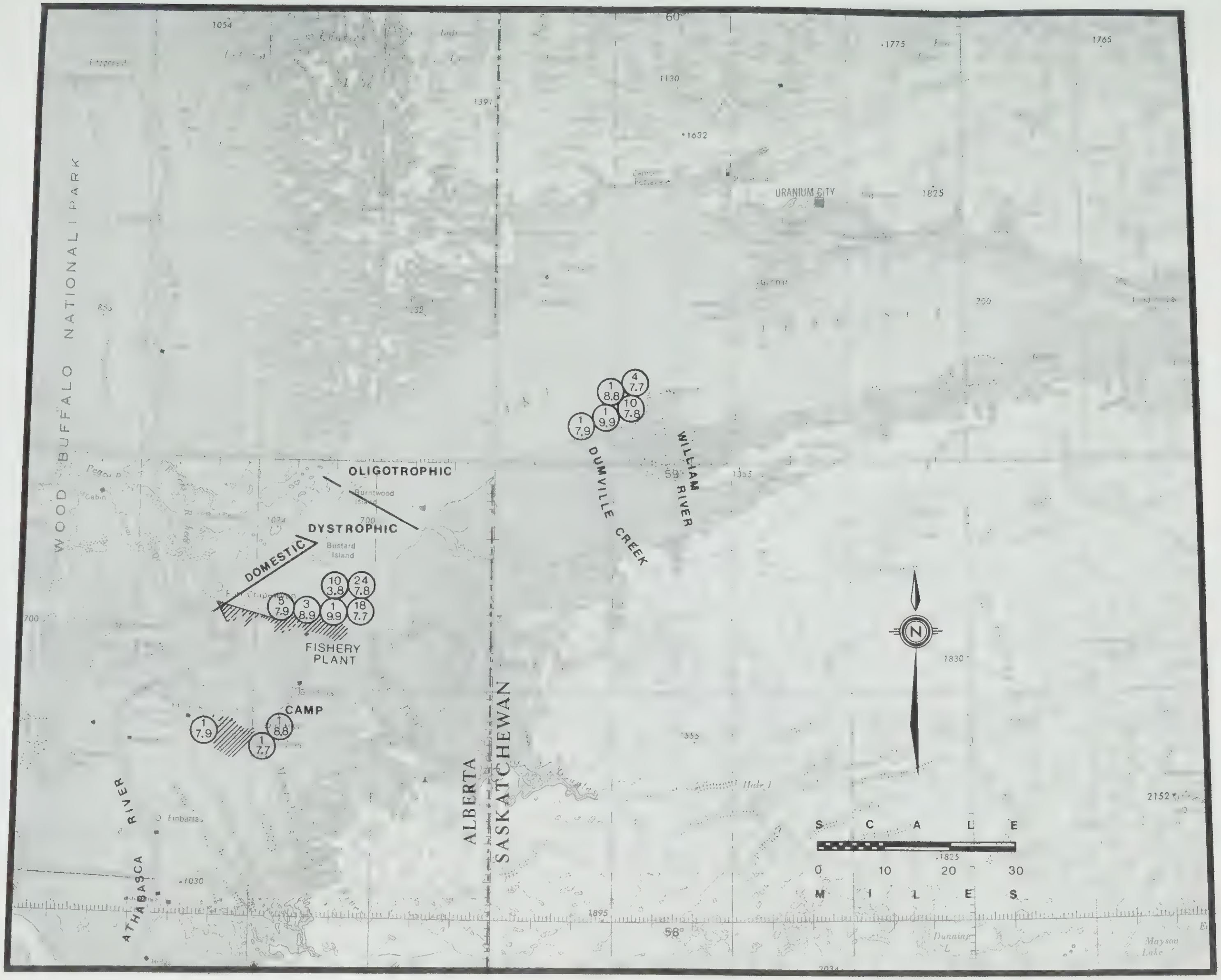

Fig. I Number of marked walleyes recaptured in two Lake Athabasca commercial fisheries after being tagged in the Richardson Lake complex in 1967 to 1969 inclusive. The year tagged followed by the year of recapture are subscript to the number of tag recoveries. The hatched areas designate closure to commercial fishing.

these studies, Richardson Lake was closed to commercial fishing in 1967, thus permitting uninterrupted spawning of this concentrated walleye population and allowing these fish to be harvested in Lake Athabasca when they returned from spawning.

The Peace River, a hydraulic dam, governs water levels in Lake Athabasca by controlling the rate of discharge of water from the lake through the Riviere des Rochers and Chenal des Quatre Fourches to the Peace River (Fig. 1). In 1968, a hydroelectric dam on the Peace River at Hudson Hope, British Columbia, became operative. The reduced discharge in the Peace River increased the rate of water drainage from Lake Athabasca to the Peace River, lowered water levels in Lake Athabasca, lowered water levels in the Richardson Lake complex, and altered the course of the Maybelle River.

The Maybelle River, a suspected spawning area for walleyes in the Richardson Lake complex, now discharged directly into Richardson Lake. In years prior to the establishment of the Peace River Dam, the Maybelle River followed a separate river channel that flowed directly into Jackfish Creek of the Athabasca River Delta (Bidgood, 1971).

Observations on the water levels and movements of walleyes in the Richardson Lake complex were conducted from March to June, 1971, and March to June, 1972. Observations on the movements of walleyes into rivers tributary to the southern shore of Lake Athabasca in Saskatchewan were conducted from late April to mid-May of 1971 to determine the extent of spawning and recruitment

of walleyes in this area. This report documents the movements of walleyes into the Richardson Lake Complex and the spawning and recruitment success of this population in these two years.

METHODS, MATERIALS, AND RESULTS

The headwater lakes of the Maybelle River contain sufficient dissolved oxygen to allow winter survival resident populations of walleyes. The populations present in these headwater lakes (Turner, 1968) are not necessarily a result of an annual spring migration from Lake Athabasca. On April 21, 1971, oxygen readings taken through the ice of one of these headwater lakes registered over eight parts per million.

Walleyes were observed on a spawning migration into Jackfish Creek of the Richardson Lake complex early in March, 1971 (Fig. 2). The migration of these fish into the Richardson Lake complex was stopped in Jackfish Creek at this time. Soundings made through the ice at the outlet channels of Richardson Lake revealed that the water under the ice was too shallow (at this time) to allow the walleyes in Jackfish Creek access to Richardson Lake or the Maybelle River, since the Maybelle River water was diverted directly into the Richardson Lake basin. On March 24, domestic gill nets set through the ice of Big Point Channel at the confluence with Jackfish Creek, and in Jackfish Creek, were capturing mature walleyes. A walleye tagged in Jackfish Creek on May 24, 1967, was recaptured in these nets on March 25, 1971.

Walleyes did not enter Richardson Lake until the ice left Big Point Channel of the Athabasca River. At this time, the Athabasca River water and the Maybelle River water raised the water level in Richardson Lake and the water flows reversed,

with Richardson Lake draining into Big Point Channel (Fig. 2). Walleyes then entered Richardson Lake and spawned within a two-week period. Until April 22, melting ice-water in Richardson Lake and the Maybelle River water trickled through Jackfish Creek to Big Point Channel. On April 23, when the ice left Big Point Channel, the water level rose in the channel and forced ice, water, and debris into Richardson Lake through Jackfish Creek. The Maybelle River flowed directly into Richardson Lake and assisted in raising the water level of the Lake (Fig. 2a). Floating ice and debris in Jackfish Creek and Richardson Lake made successful sets of fishing gear in these waters impossible. On April 30 the flow of water reversed, and Richardson Lake and the Maybelle River drained through Jackfish Creek into Big Point Channel (Fig. 2b). Gill nets set after April 30 in the outlet channels from Richardson Lake captured mature and ripe walleyes. On May 13, 150 yards of gill nets set in Richardson Lake yielded 436 walleyes. All the females in the 230 fish sampled from this catch had completed spawning.

Mature and ripe walleyes migrating into the Richardson Lake complex were not migrating up the Maybelle River but were spawning in Richardson Lake. On April 23, 1971, when breakup of the Maybelle River was still in progress, a fyke net was set to capture upstream migrants in the river. The crib was examined daily and the net was fished continually until June 2. Northern Pike, _Esox lucius_ L., white suckers, _Catostomus commersoni_ (Lacepede), and longnose suckers, _Catostomus catostomus_ (Forster) were captured on spawning migrations up the Maybelle

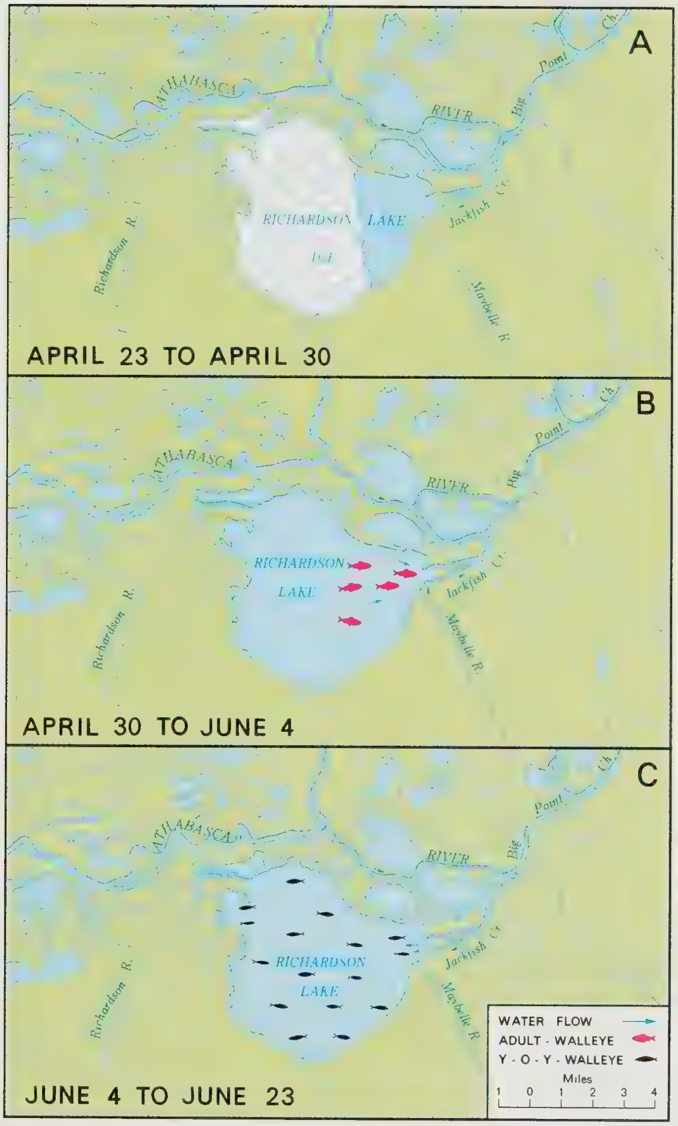

FIG. 2 Flow of water and migration of adult and young-of-the-year walleye into and out of the Richardson Lake complex during the spring and early summer of 1971

River, but only two walleyes were captured during the period fished.

A migration of walleyes up the Maybelle River probably occurred prior to 1968 when higher water levels were present in the Richardson Lake complex. Turner (1968), when conducting surveys of lakes located at the headwaters of streams tributary to the Athabasca River Delta and Lake Athabasca south of the Delta in Alberta, noted the presence of walleyes in only six of 19 lakes surveyed. All six lakes were located on the headwaters of the Maybelle River. The fish in these lakes probably originated from the spawning migration of walleyes into the Richardson Lake complex, with some fish remaining as residents.

Walleyes migrating into the Richardson Lake complex early in 1971 (March to April) did not have access to the Maybelle River. Samples of walleyes from the Richardson Lake complex in the springs of 1965 to 1969 inclusive included both spent and maturing females. No maturing fish were present in the 1971 sample. Immediately after spawning, under conditions of warm water and an abundant food supply, female walleyes begin developing new gonads and eggs for the following year. The maturing walleyes in these samples probably spawned a considerable period of time ahead of the spent individuals. These fish would have moved into the Richardson Lake complex and spawned in the warm waters of the Maybelle River system ahead of the fish that moved in and spawned in Richardson Lake when the ice left the lake. Under the low water regimes now present in the Richardson Lake complex, this movement of the early arrivals

(March to April) into Jackfish Creek and up the Maybelle River is not possible. In addition, during May and June of 1965 to 1969, spent walleyes could be taken by angling in the deep pools of the Maybelle River. The proportion of the spawning migration of walleyes into the Richardson Lake complex that utilized the Maybelle River system prior to 1968 is unknown.

Gill nets are an inefficient method of sampling the spawning migration of walleyes into the Richardson Lake complex. There is no doubt that the Richardson Lake walleye population is a major contributor to the Lake Athabasca commercial harvest of this species. Gill nets readily filled with debris when set in the outlet channels of Richardson and did not fish efficiently. In an attempt to assess the number of days that adult walleyes remained in Richardson Lake relative to water levels and flows, 418 walleyes were captured, tagged, and released in the outlet channels from April 30 to June 7. No marked fish returning from Richardson Lake were recaptured in these nets. Twenty-one of these marked fish were reported recaptured in the Alberta commercial fishery on Lake Athabasca.

The walleyes in Richardson Lake could be spawning on the western shore of Lake Athabasca. The tributary waters here discharge clean, clear water into the lake over a sand bottom. Observations from aircraft, which were subsequently verified with gill net sets, revealed that lake whitefish were actively feeding in large numbers in the clear waters along the west shore of the Lake (Fig. 2). Walleye, a crepuscular species (Ali and Anctil, 1968) that avoids direct sunlight, could be spawning

in this area at night. Lake whitefish could be feeding on the spawn and/or young-of-the-year walleyes.

Post-spawning walleyes from the Richardson Lake complex are migrating along the southern shore of Lake Athabasca to the deeper waters in the Saskatchewan portion of the Lake (Fig. 1). Streams on the Alberta side were examined for spawning migrations. Walleye were not observed migrating up Crown Creek, a tributary of Old Fort Bay, in April. On April 22, 1971, a gill net was set across Crown Creek. No nets were set in the other two major tributary streams of Old Fort Bay, Old Fort River, and Harrison Creek, since at this time they were still ice covered. The Crown Creek net, pulled on April 24, contained no fish. The net was filled with debris and was ineffective.

The streams tributary to the southern shore of Lake Athabasca in Saskatchewan are mot major spawning and recruitment areas for walleyes. Pound nets, hoop nets, gill nets, and seines were employed from April 27 to May 20, 1971, to capture fish migrating into the following four drainage systems of the south shore of Lake Athabasca: William River, Ennuyeuse Creek, Dumville Creek, and West Dumville Creek (Fig. 1). No mature walleyes were captured in these four drainage systems (Table 2). One immature walleye (FL 4.3 inches) was captured in a seine haul in Ennuyeuse Creek and was a member of the 1970 year class. The species of fish captured in these four tributary streams is tabulated in Table 2.

Young-of-the-year (y-o-y) walleyes (TL: $\bar{x}$ =19.3mm) were actively

Table 2. Species and number of fish collected in four tributary streams of the south shore of Lake Athabasca between April 27 and May 20, 1971.

Species	Tributary Stream			
	William River	Ennuyeuse Creek	Dumville Creek	West Dumville
Northern pike	126	105	40	89
White sucker	187	4	31	1
Longnose sucker	130	24	71	2
Lake whitefish	30	38	1	0
Round whitefish	1	0	0	0
Grayling	3	0	129	0
Burbot	3	1	1	2
Sculpin	1	0	3	0
Spottail shiner	0	4	5	57
Emerald shiner	0	18	1	12
Lake chub	556	0	1	30
Ninespine stickleback	102	0	1	8
Trout-perch	0	0	2	2
Walleye	0	0	0	1
Brook stickleback	0	2	0	0

swimming in Richardson Lake and leaving through Jackfish Creek to Big Point Channel (Fig. 2c). Trawls with meter nets and half-meter nets captured y-o-y walleyes in Jackfish Creek as early as June 3, 1971. Trawls undertaken at several locations in Richardson Lake from June 17 to June 20 captured y-o-y walleyes. These fish were distributed throughout the entire lake. Y-o-y burbot, suckers, spottail shiners, emerald shiners, and mountain whitefish were also captured in these meter net tows, as well as adult ninespine sticklebacks.

In 1971, a sample of 241 walleyes captured in gill nets in Richardson Lake on May 13, 1971, was examined for sex. Scales were removed for age determination. In June of the same year, a sample of 499 walleyes was collected from the commercial 4-inch mesh nets set in the Alberta waters of Lake Athabasca. The fork length and total length of each fish was recorded, and scales were removed posterior to the pectoral fin and below the lateral line on the left side of each specimen for age determination. In July and August of the same year, a sample of 500 walleyes was collected from the 4 3/4-inch mesh nets set in the Saskatchewan waters of Lake Athabasca. These three samples of fish were compared to determine if the fish in these three areas were members of the same population.

The Richardson Lake sample had a higher proportion of four-year-old fish than did either the Alberta or Saskatchewan sample of walleyes (Fig. 3). Male fish with four and five completed annuli dominated the Richardson Lake sample. Five-year-old fish were dominant in both the Lake Athabasca samples. Rawson (1957), in

studies of walleyes in Lac La Ronge, observed that male walleyes arrive first on the spawning beds and remain longer than the female fish. Bidgood (1971) found that four-year-old male walleyes were predominant in the Richardson Lake samples since they mature for the first year of spawning one year earlier than the females. These two factors probably account for the large numbers of male fish and the larger numbers of four-year-old fish in this sample from the Richardson Lake spawning population.

The sample of walleyes from the Saskatchewan portion of the Lake had a larger number of five-year-old fish than did the sample from the Alberta portion of the Lake. The Alberta fishery that precedes the Saskatchewan fishery used 4-inch stretched mesh gill nets, whereas the Saskatchewan fishery used 4 3/4-inch stretched mesh nets. Gill net selection for larger fish in Saskatchewan could account for the higher proportion of five-year-old fish in the Saskatchewan sample.

A comparison of the growth rates of walleyes from the Alberta fishery, captured with 4-inch stretched mesh gill nets, and the Saskatchewan fishery, with 4 3/4-inch stretched mesh gill nets, is presented in Table 3. Three year-classes of walleyes were larger in the samples taken from the Saskatchewan commercial fishery nets than those from the Alberta commercial nets. The Saskatchewan sample was collected a month to a month and a half later than the Alberta sample of post-spawning walleyes. The Saskatchewan fish had a month's summer growth over the Alberta sample. Sexual dimorphism in growth occurs in this walleye

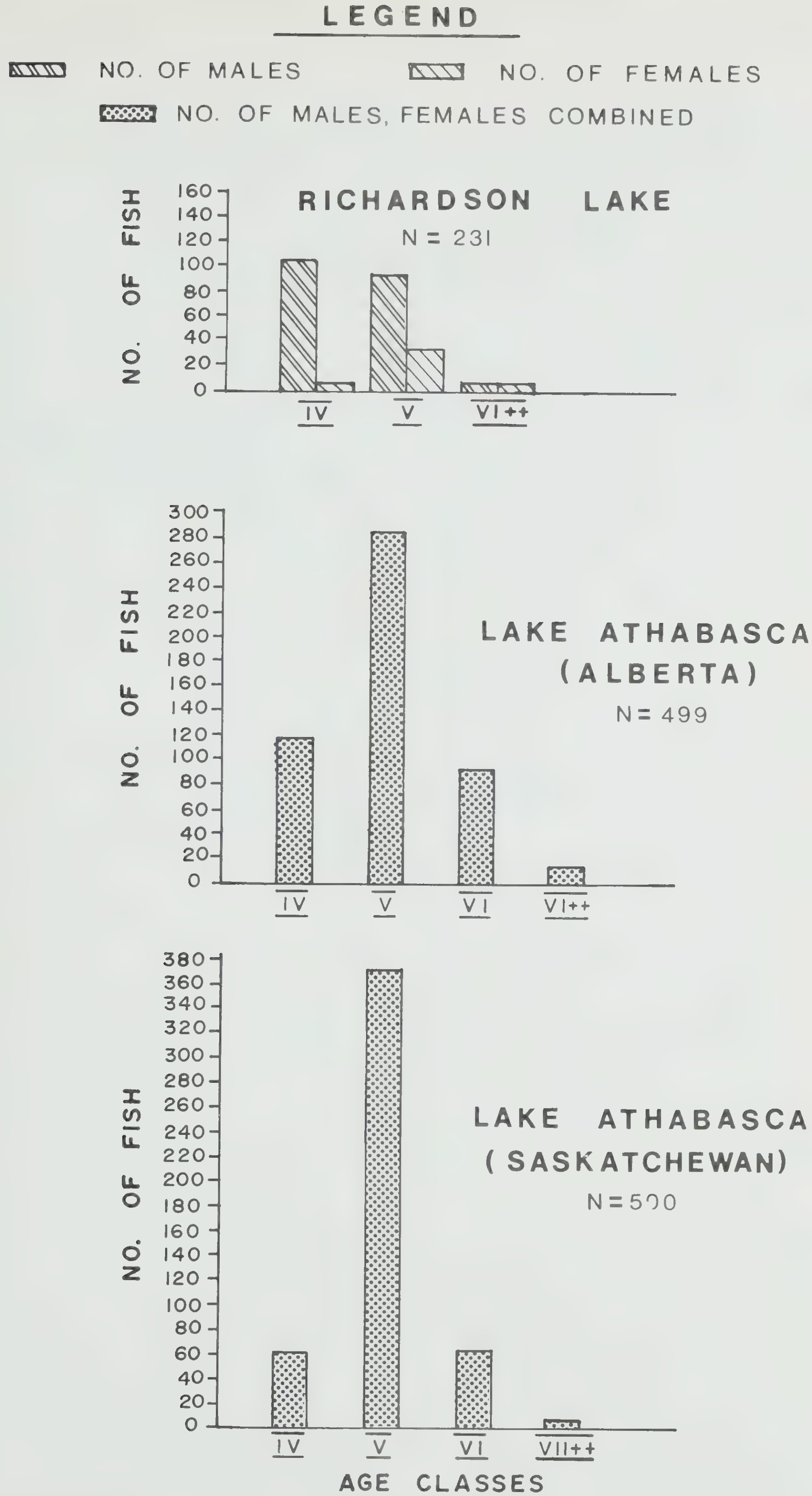

Fig. 3 Number of walleyes in four age classes in samples collected at three locations associated with Lake Athabasca. Fish with seven annuli or more are all included in the sample with seven annuli.

Table 3. Mean fork length (mm) of samples of four age classes of walleyes from Alberta and Saskatchewan waters of Lake Athabasca. Highly significant, p=.01 (>>); significant, p=.05 (>); and non-significant (n.s.) comparisons of means are indicated. The sample size in each age class is presented in brackets. Male and female fish were combined in these samples.

Location \ Number of Annuli	IV+		V+		VI+		VII++*
	Mean Fork Length (mm) / and Sample Sizes						
Alberta	388.5	<<	407.5	<<	426.5	n.s.	437.8
	(115)		(283)		(88)		(13)
	∧		∧∧		∧∧		n.s.
Saskatchewan	398.0	<<	413.7	<<	438.8	n.s.	473.2
	(61)		(370)		(64)		(5)

*VII+ or older

population (Bidgood, 1971). The growth rates of the male and female fish in these samples were not compared separately. These factors complicate a comparison of the growth rates of these two samples of walleyes.

To conclude, the Richardson Lake, Alberta (Lake Athabasca), and Saskatchewan (Lake Athabasca) commercial fisheries are probably harvesting the same populations of walleyes. The results of the tagging studies conducted in Richardson Lake in 1967 to 1969 (Fig. 1) support this conclusion. Walleyes spawning in Richardson Lake are major contributors to both the Alberta and Saskatchewan commercial fisheries for this species.

In 1972, domestic gill nets, set through the ice at the confluence of Jackfish Creek with Big Point Channel (Fig. 3) in March and April, yielded over 100 walleyes per overnight set. A walleye tagged on May 25, 1967, in Richardson Lake was recaptured on April 23, 1972, in these nets. These walleyes did not have access to Richardson Lake at this time. Breakup of the Athabasca River on May 6, 1972, recharged Richardson Lake with water (Fig. 4a). Strong easterly winds at this time forced the ice to the western shore of Richardson Lake where it melted in situ. From May 8 to May 31, the water in Richardson Lake flowed mainly out of the Lake through Jackfish Creek to the Athabasca River. Reversal of water flows into Richardson Lake occurred periodically throughout this period. The hydraulic pressure of Lake Athabasca, increased by strong easterly winds, reduced the rate of flow of the Athabasca River through the Athabasca River Delta to Lake Athabasca and forced Athabasca River water into

FIG. 5 East view of outlet channels from Richardson Lake (bottom) to Jackfish Creek (top) on May 31, 1972. The Maybelle River Channel is located on the extreme right of the picture

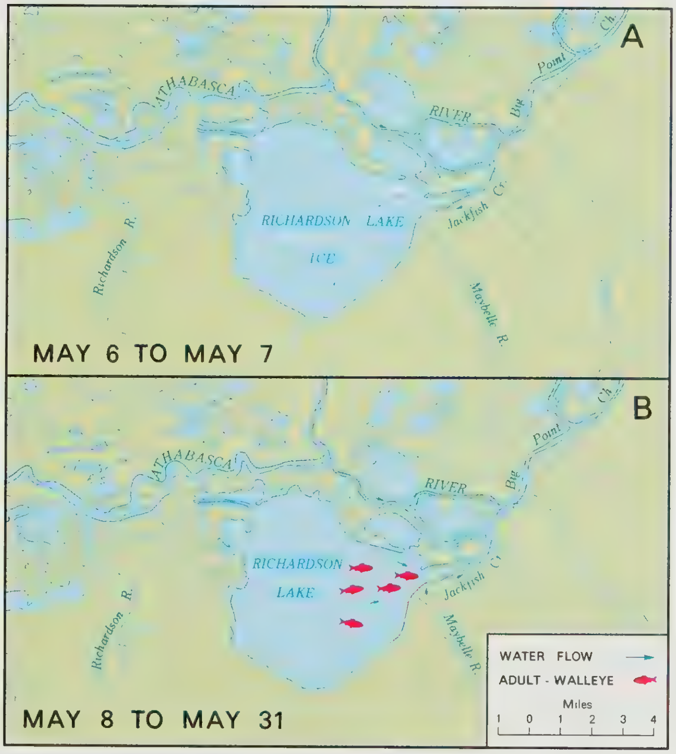

FIG. 4 Flow of water and migration of adult walleye into and out of the Richardson Lake complex during the spring of 1972

Richardson Lake.

A total of 2,410 walleyes, captured in 4-inch stretched mesh gill nets set in the northwestern waters of Richardson Lake, were tagged with numbered, orange, Floy anchor tags between May 8 and May 30, 1972 (Fig. 4b). The majority of the fish tagged were mature and ripe, and tagging mortality was low. After this date, the gill nets captured mainly spent individuals and tagging operations were terminated due to high post-tagging mortalities. These gill nets yielded over 100 walleyes per 50-yard set of 4-inch gill nets fished for from one to two hours. When Richardson Lake was commercially fished, a harvest of 200,000 pounds of walleyes in five days was not uncommon (Table 1). From these data it is estimated that the spawning population of walleyes in Richardson Lake ranged from 500,000 to 1,000,000 fish.

Observations of the water levels in the Richardson Lake complex on May 31, 1972, revealed that the water levels in the Lake at this time were similar to those observed in the complex at the same time of year in 1965, 1966, and 1967 (Fig. 5). The Maybelle River at this time was flowing past Richardson Lake and into Jackfish Creek in its own confined channel. The four outlet channels from Richardson Lake to Jackfish Creek were beginning to reappear. Higher water levels in Richardson Lake in May of 1972 accompanied higher water levels in Lake Athabasca.

SUMMARY

1971

1. Mature walleyes moved into Jackfish Creek earlier than March 25 but did not have access to Richardson Lake or the Maybelle River at this time, since Richardson Lake was frozen to the bottom and the Maybelle River water was dispersed under the ice of Richardson Lake.

2. Richardson Lake was recharged with water after the ice left the Athabasca River on April 23. When the water level in Big Point Channel dropped, Richardson Lake drained into Big Point Channel through Jackfish Creek. Mature walleyes then moved into Richardson Lake.

3. Walleyes were not observed on a spawning migration up the Maybelle River but were observed spawning in Richardson Lake.

4. There were no spawning populations of walleyes noted in streams tributary to Old Fort Bay of the southern shore of Lake Athabasca in Alberta or streams tributary to Lake Athabasca in Saskatchewan.

5. Young-of-the-year walleyes were distributed throughout Richardson Lake and were migrating out of the complex through Jackfish Creek.

6. Samples of walleyes collected from Richardson Lake, the Alberta portion of Lake Athabasca, and the Saskatchewan

portion of Lake Athabasca did not indicate that these were segregated populations of fish.

1972

1. In March and April, mature walleyes were captured at the confluence of Jackfish Creek with the Athabasca River. Access to Richardson Lake was restricted at this time.

2. Richardson Lake was recharged with water after the ice left the Athabasca River on May 6. Mature walleyes entered the Lake and spawned.

3. Walleyes appeared to be spawning in the northwestern portion of the Lake.

4. Water levels in Richardson Lake were higher than those of the preceding year, as were the water levels in Lake Athabasca.

5. The Maybelle River followed the same course as was observed in 1965, 1966, and 1967.

DISCUSSION

Richardson Lake is now dependent on spring breakup and the increased water discharge in the Athabasca River to obtain sufficient water to permit walleyes to enter and spawn in the Lake. In the past, when water levels were higher on Lake Athabasca, Richardson Lake probably held water throughout the winter months. Prior to 1968 and in 1972, the Maybelle River flowed via its own bed directly to Jackfish Creek and Big Point Channel. On April 23, 1967, aircraft observations recorded that the Maybelle River was open and flowed directly to Big Point Channel when the Athabasca River and Richardson Lake were still under ice cover. In May of the same year, gill nets were set in the Maybelle River in a confined channel of water that was over 10 feet deep. The hydraulic pressure of the water in Richardson Lake prevented the Maybelle River from entering the Lake at this time. These conditions present in Richardson Lake prior to 1968 would have allowed spawning walleyes, arriving in Jackfish Creek in March and April prior to breakup in the Athabasca River, access to Richardson Lake and/or the Maybelle River.

The discharge of water in the Athabasca River in the spring months of 1971 was above the average discharge of the River for that time of year (Fig. 6). The high discharge in the Athabasca River in April and May of 1971 poured water into Richardson Lake and therefore allowed the walleyes to enter. In 1972, a similar situation occurred in Richardson Lake when the highest spring discharge in eight years in the Athabasca River was recorded. A low discharge of spring water in the Athabasca River similar to

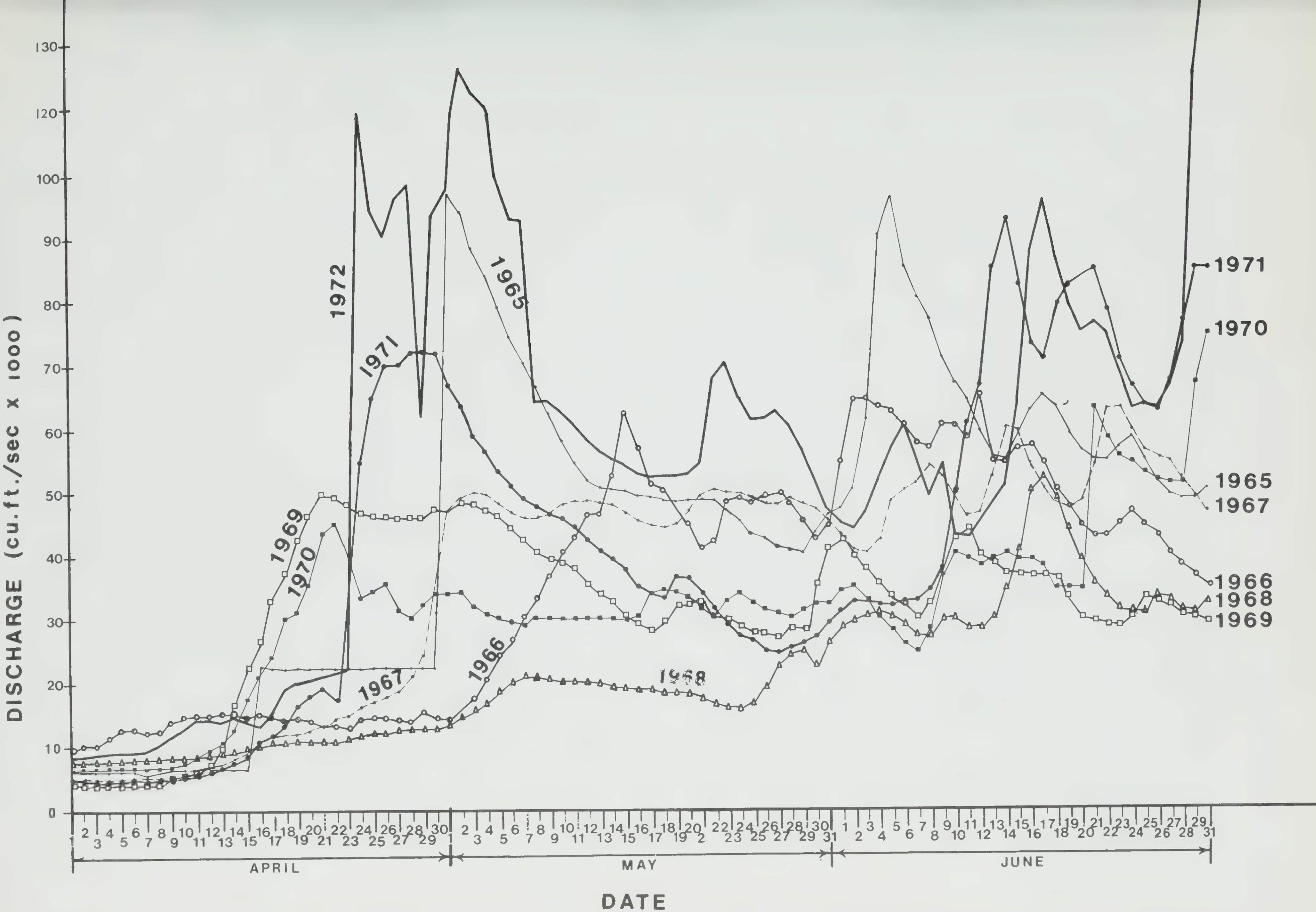

Fig. 6 Daily discharge of water in Athabasca River for three consecutive months of eight consecutive years.

that of 1968, with a low water level in Lake Athabasca, may not be sufficient to recharge Richardson Lake with water to the same degree as that noted in 1971 and 1972. Such a reduction in water levels in the lake or a lower Athabasca River discharge might prevent the spawning population of walleyes from entering the Lake and successfully spawning. If this were the case, recruitment to the Richardson Lake population could be eliminated.

In 1972, higher water levels in Lake Athabasca and Richardson Lake than those observed in the spring of 1971 were present. Apparently, an ice dam on the Peace River at breakup increased the hydraulic pressure of the Peace upstream above this dam, reduced the rate of discharge of water from Lake Athabasca through the outlet channels, and maintained Lake Athabasca at a higher water level. Higher spring water levels in Lake Athabasca accompanied higher spring water levels in Richardson Lake. If these water levels in Lake Athabasca were approached in the winter months (March, April), the Maybelle River would follow its own channel to Jackfish Creek when it opens in April and allow the early arriving mature walleyes at the confluence of Jackfish Creek and Big Point Channel access to the Richardson Lake complex.

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SECTION F

STATUS OF GOLDEYE, *Hiodon alosoides*, POPULATIONS IN THE PEACE-ATHABASCA DELTA

by

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CANADIAN WILDLIFE SERVICE

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PURPOSE

The purpose of this study was to appraise the status of goldeye populations in the Peace-Athabasca Delta, to consider the effects on these populations of changes in water regimes brought about by watershed management in the upper Peace River, and to make recommendations with regard to any management of the Delta waters which will affect goldeye populations.

BACKGROUND

The goldeye is a freshwater fish belonging to the mooneye family, Hiodontidae, representatives of which are found only in North America. In Western Canada, the goldeye is found in the Lake Winnipeg drainage system, which includes the North and South Saskatchewan Rivers, parts of the Churchill River, and the Athabasca River, Peace River, Slave River, and Mackenzie River systems. This distribution probably reflects dispersion along waterways associated with post-glacial Lake Agassiz.

The goldeye has been commercially fished at various times during this century in areas where it occurred abundantly. These fisheries have declined because of over-exploitation of the stocks. Populations of goldeye in the Peace-Athabasca Delta supported a substantial commercial fishery from the late 1940's until the middle 1960's, with production dropping off drastically between 1963 and 1966 (Table 1). Average annual production was 144,000 pounds for the earlier years but dropped to less than 25,000 pounds for the last four years. At a gross price of approximately 10¢ per pound to the fishermen, this

Table 1. Goldeye harvest records for Lake Claire.[1]

Year	Harvest in Pounds
1948	119,000
1949	240,000
1950	71,405
1951 to 1953	(operations suspended)
1954	240,000
1955	(not fished)
1956	176,349
1957	133,016
1958	(not fished)
1959	141,236
1960	102,160
1961	93,682
1962	102,925
1963	22,000
1964	1,451
1965	46,857
1966	27,578

[1]Records supplied by the Canadian Wildlife Service.

production was of considerable importance to the economy of the Fort Chipewyan community. There has been no commercial fishery for goldeye in the Delta since 1966.

Domestic fishermen from Fort Chipewyan reported an increasing number of small goldeye in the area during the late 1960's. Larger goldeye in fair numbers were caught during the summer of 1970. This suggests that goldeye populations were recovering from the decline noted above.

Goldeye in the Delta are believed to be part of a larger population mainly resident in the Peace River. Spring flood conditions in the lower Peace River stimulate adult goldeye to migrate into the shallow turbid waters of the Delta, particularly the Lake Claire - Mamawi Lake area, where they spawn (Fig. 1). Adults are said to remain in the shallow waters of this area until late summer when they return to the Peace River. Young goldeye also supposedly utilize the shallow waters of the Delta as nursery grounds, but their subsequent movements had not been observed prior to this study.

METHODS

A pound net was set in the Prairie River in early May of 1971 to catch goldeye migrating into Lake Claire, but strong currents combined with much debris made the set inoperable.

Gill nets, therefore, were used during May to collect samples of adult goldeye migrating into the Lake Claire - Mamawi Lake area from the Peace River via the Chenal des Quatre Fourches. The daily catch was recorded and some data on individual fish (including size, sex, and state of maturity) were collected. Samples of scales were taken from each fish to assist in determining their age. Stomach contents of some fish were examined. Similar gill net sampling was undertaken in July, early August, late September, and October to monitor the movements of adult goldeye in the Delta. Additional gill net sampling was done during the winter months in the Delta and also in the Peace River to determine the winter distribution of the goldeye.

Small trawls were used during July, August, and October to collect young-of-the-year goldeye, in order to estimate the success of natural reproduction and to document the seasonal distribution pattern of these young fish. Samples of planktonic fauna were collected simultaneously with the small fish samples taken during July and August to determine what food organisms were available. Stomach contents of the young fish were examined.

Supplementary meteorological and hydrological observations were

Fig. 1 Peace-Athabasca Delta

made to assist in interpreting the effects of such phenomena on the goldeye in the Delta area.

RESULTS

SPRING SPAWNING MIGRATIONS

Peace River floodwaters started backing along the Chenal des Quatre Fourches and into the Lake Claire - Mamawi Lake area in late April, creating breakup conditions in the Delta about two weeks earlier than the average date of May 10. Adult goldeye were first noted at the Quatre Fourches on May 6 and peak numbers were caught in the Prairie River on May 12 and 13. On May 17 approximately 50 percent of the female fish sampled had completed spawning, and by May 20 all goldeye caught in the Prairie River had completed their spawning cycle. Samples collected at different points indicate that goldeye spawned in various areas from the Chenal des Quatre Fourches to Lake Claire and possibly beyond this. Schultz (1955) reported that in 1954 the goldeye appeared to have completed spawning by June 8.

Water temperatures in the Prairie River ranged from the high 40's to 60°F during the first three weeks of May, 1971. Kennedy and Sprules (1967) state that spawning begins when the mean water temperature is 50 to 55° and continues for three to six weeks. It would appear that in 1971 the goldeye spawning cycle started early in the Peace-Athabasca Delta and was completed in less than three weeks. This early and short spawning cycle in 1971 is attributable to an early breakup accompanied by continuing warm weather during the month of May.

Hydrological records for April and early May are meager, but it appears that the waters rose rapidly in late April, bringing

levels to between 684.0 feet above sea level and 685.0 in the Quatre Fourches area by early May. Water levels on Lake Claire and the Prairie River were 685.0 or more during most of May, with a current usually running easterly in the Prairie River from Lake Claire to Mamawi Lake. Wind seiches generated temporary reversals of this predominantly eastward flow of water. By late May there was a pronounced decline in the water levels of Lake Claire and the Prairie River, and travel by power boat across Mamawi Lake was becoming difficult.

The technique of sampling the goldeye run with gill nets did not provide data for estimating the actual numbers of fish which migrated into the shallow waters of the Delta. However, local fishermen commented that the numbers and sizes of the goldeye were reminiscent of earlier years when the commercial fishery flourished. Data on the age and size composition of an early season sample taken by Schultz in 1954 are compared with the 1971 data (Table 2). The average age of the 1971 sample is younger because of fewer old fish and a higher percentage of young fish. All goldeye in the 1971 sample were mature except for one male fish. Kennedy and Sprules (1967) reported that no six-year-old female goldeye collected from Lake Claire in 1947 and 1948 were mature; only 2 percent of the seven-year-old females were mature, and 55 percent were mature at age eight. Male goldeye usually mature at an earlier age than female fish.

A comparison of the growth rates of fish from the 1954 and the 1971 samples offers a possible explanation for these differences in maturity (Fig. 2). The growth rates of the fish in the 1971

Table 2. Age composition, size distribution, and sex ratio of goldeye samples taken from comparable gill nets in 1954[1] and 1971.

Sample Year	Age Group	Number Caught	Percent of Total Catch	Fork Length millimeters (MEAN)	Body Weight grams (MEAN)	Sex Ratio M/F
1954	6	0	-	-	-	-
1971		42	16.8	290 (321) 349	260 (374) 480	22/20
1954	7	14	4.0	285 (304) 318	227 (278) 312	10/4
1971		127	50.8	304 (332) 345	330 (399) 550	74/53
1954	8	159	45.4	280 (328) 374	255 (340) 511	81/78
1971		70	28.0	322 (347) 368	340 (459) 570	32/38
1954	9	149	42.6	317 (356) 400	312 (397) 539	37/112
1971		8	3.2	338 (352) 375	410 (489) 590	3/5
1954	10	22	6.3	336 (367) 406	369 (471) 567	0/22
1971		3	1.2	344 (362) 375	420 (510) 600	0/3
1954	11	4	1.1	343 (383) 393	369 (476) 567	0/4
1971		0	-	-	-	-
1954	12	2	0.6	355 (398) 438	482 (581) 680	0/2
1971		0	-	-	-	-

[1]Data from Schultz, 1955.

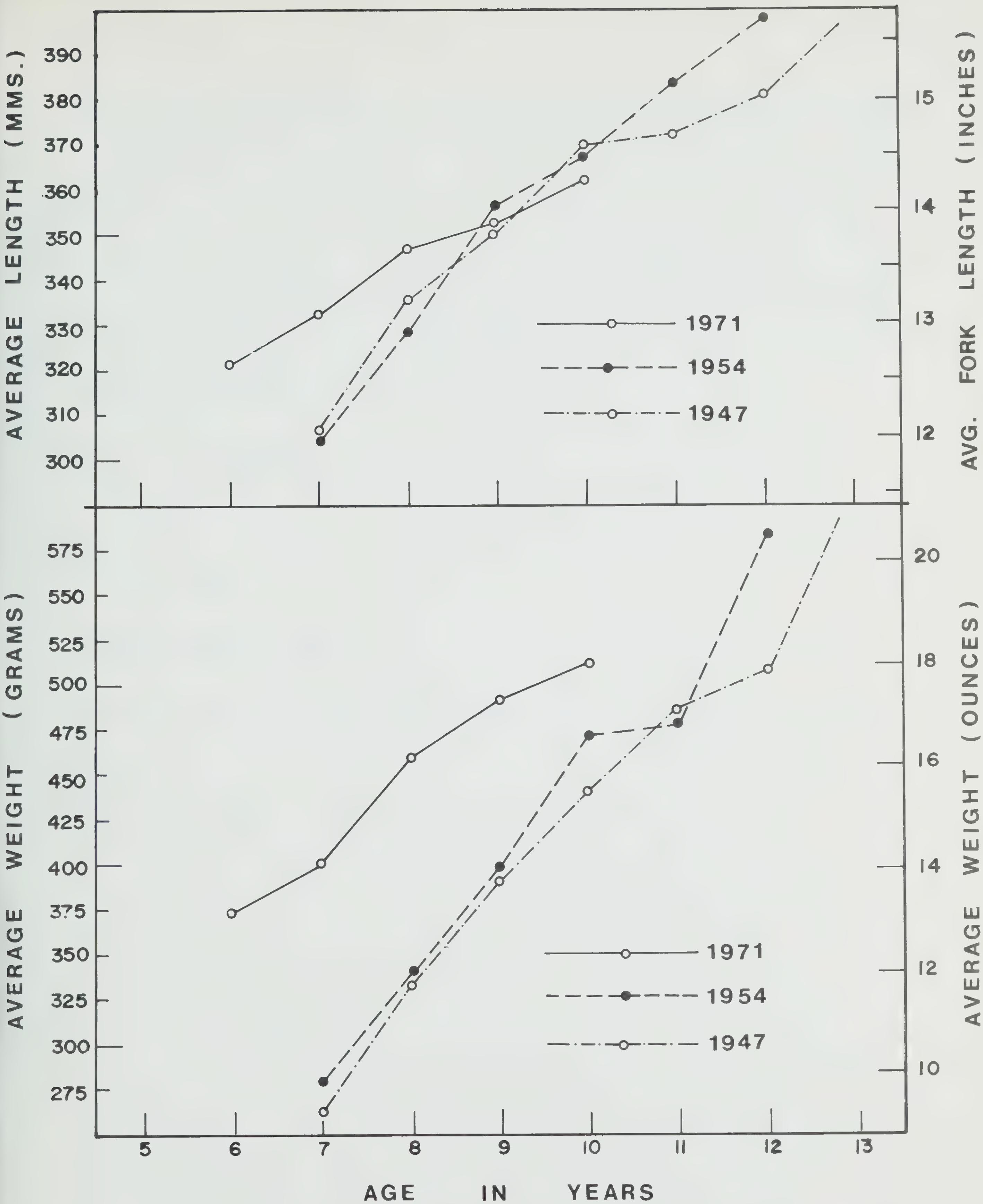

Fig. 2 The relationship between age and average size (length and weight) in goldeye samples taken from Lake Claire in 1947, 1954 and 1971.

sample are considerably greater than those for the 1954 fish. Size, as well as age, is a factor in the onset of sexual maturity. Goldeye in the Peace-Athabasca Delta are maturing at an earlier age than in the past because of faster growth rates. The accelerated growth rates in recent years may be the result of lessened competition amongst goldeye, due to their decreased numbers during the early 1960's.

From the foregoing observations, it is concluded that a substantial run of mature goldeye entered the shallow floodwaters of the Delta in the spring of 1971 and spawned in various areas.

REPRODUCTIVE SUCCESS

Trawling operations for small fish were conducted at 52 sampling stations on Lake Claire, Prairie River, Mamawi Lake, and the Quatre Fourches area during July and August. A total of 158 young-of-the-year goldeye and 71 walleye were collected. No young goldeye were found in the Chenal des Quatre Fourches during this period, but one young walleye was taken. In the lakes, sample tows were usually made within one mile of shore. Young goldeye were widely distributed around the periphery of Lake Claire and were abundant off Spruce Point near the mouth of the Birch River in early July. A single open water tow in Lake Claire produced no small fishes. In Mamawi Lake young of both species were found only in the large bay south of Prairie River.

Calculations based on the size of the area sampled by each tow, the average number of small fish caught in each tow, and the

total area of shoreline habitat in each body of water sampled, give the following estimates of young-of-the-year fish.

WATERS	SPECIES	
	Goldeye	Walleye
Lake Claire	2,800,000	120,000
Prairie River	18,000	4,300
Mamawi Lake	210,000	315,000
Quatre Fourches (west channel)	2,700	11,000
Totals	3,030,700	450,300

The trawling operation was not designed to compile data for population estimates; therefore, the foregoing numbers should be interpreted cautiously. They are absolute minimum estimates of the numbers of young goldeye and walleye in the Lake Claire - Mamawi Lake area. The evidence does indicate that natural reproduction of goldeye occurred in the Delta region under the water regime which prevailed in 1971. Walleye also reproduced in the Delta waters. Young goldeye were most abundant in Lake Claire and in the Prairie River. Young walleye were most abundant in Mamawi Lake and in the channels in the vicinity of Quatre Fourches. Since there are no comparable data for earlier years, the success of the 1971 spawning cycle can be measured only by reference to the strength of this year class in the future adult population.

FOOD AND GROWTH OF YOUNG GOLDEYE

Samples of potential food organisms for young fish, collected simultaneously with the small-fish samples, revealed an exceptional abundance of crustacean zooplankters and aquatic insects in Lake Claire, Mamawi Lake, and the Prairie River. In the Quatre Fourches area and the Chenal des Quatre Fourches these forms were much less abundant. Gallup and van der Giessen (1971), in a plankton survey of the Delta waters, similarly reported that crustacean zooplankters were very abundant and noted that the highest biomass of these organisms occurred in Lake Claire.

An analysis of the stomach contents of young goldeye collected in the Delta revealed that they were feeding heavily on the larger species of zooplankters and also utilizing many small aquatic insects. None of the goldeye were found with empty stomachs. There was no evidence to suggest that they were selecting a particular species of food organism. *Daphnia pulex* was the most abundant food organism present in the aquatic habitat; this crustacean appeared most frequently in the stomachs of young fish. In the Quatre Fourches area *Leptodora kindtii* occurred with equal frequency in the stomachs of young goldeye. A number of smaller species of crustaceans reported by Gallup and van der Giessen were not found in young goldeye stomachs. It would appear that these fish do select food items by size. In late July the goldeye fed more extensively on corixid insects, which are much larger than the crustacean organisms utilized by the smaller fish in early July. This also

suggests some size selection, but the change may reflect changes in abundance of food items. Corixids were much more abundant in late July and August.

Young-of-the-year goldeye displayed excellent growth. Comparative data confirms that in the summer of 1971, young goldeye from the Peace-Athabasca Delta exceeded growth rates previously recorded for other populations in Canada (Fig. 3). However, growth decreased in the fall; by October, their average length was less than that reported by Kennedy and Sprules (1967) for young goldeye in the Saskatchewan River Delta in 1945 and 1946. Although growth had slowed, by October these young goldeye were 50 percent longer than those reported by Kennedy and Sprules (1967) for the Peace-Athabasca Delta in 1946, 1947, and 1948.

The early open water season with continuing warm weather and an abundant food supply were probably the major factors stimulating this rapid growth. Large size in the fall may have an important bearing on the future survival of young goldeye. If so, the 1971 year class may be extremely successful.

FOOD AND GROWTH OF ADULT GOLDEYE

In 1971, adult goldeye utilized insect fauna more extensively than in 1947, but very few small fish appeared in their diet (Table 3). Small pike, in particular, were virtually absent. On the other hand, while plankton (presumably crustacean zooplankton) appeared rarely in the diet of adult goldeye in 1947, this component of the planktonic community not only

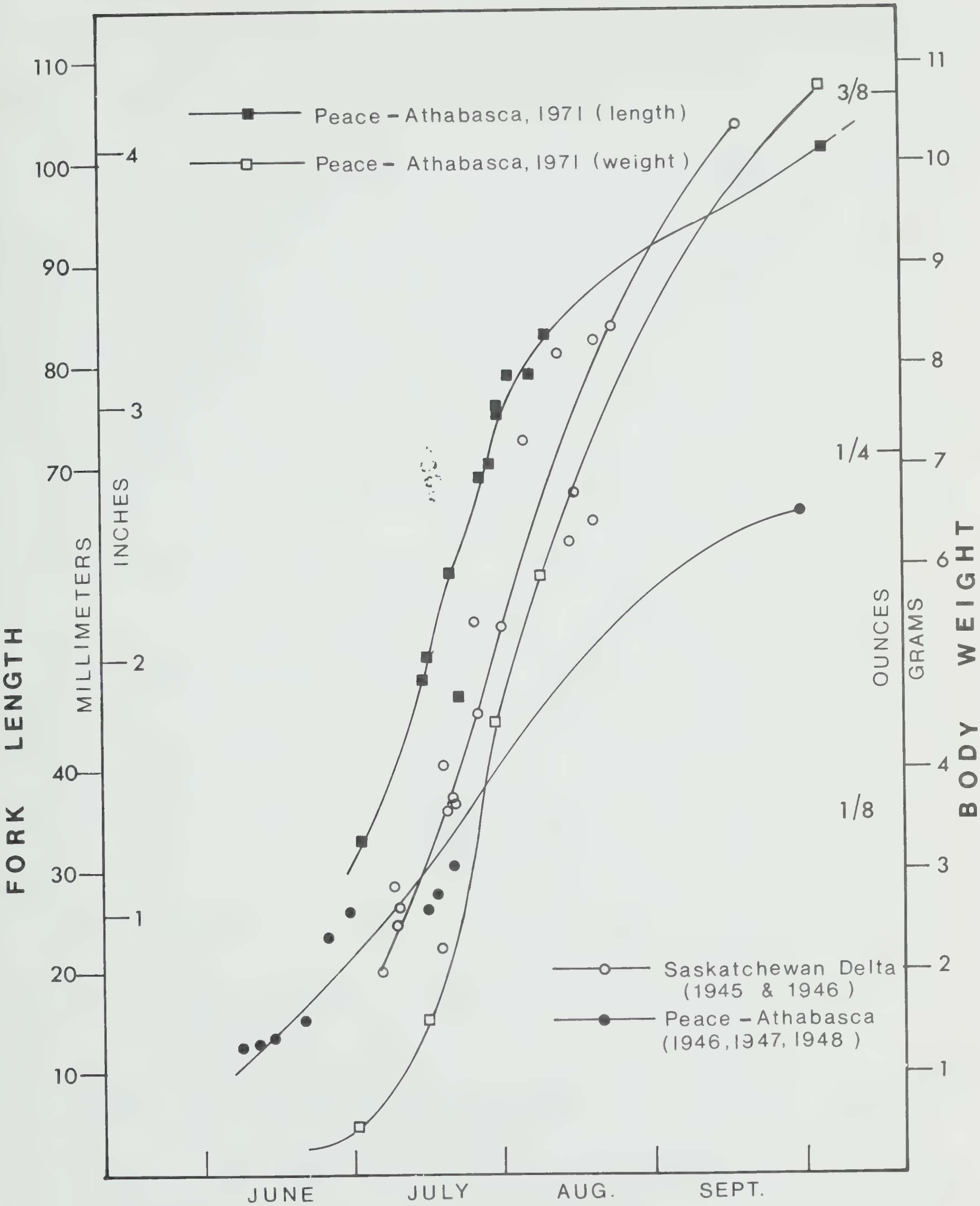

Fig. 3 The relationship between age and average size (length and weight) in young-of-the-year goldeye from different waters and in different years.

Table 3. Stomach contents of adult goldeye collected from two locations on the Peace-Athabasca Delta in 1947[1] and 1971.

	Lake Claire - 1947		Prairie River - 1971	
	May	July	July	August
Number examined	49	92	76	60
Percentage empty	2%	8%	8%	17%
Number with food	48	85	70	50
Percentage[2] with the following:				
Corixids	77	2	86	80
Other aquatic insects	52	11	24	26
Other insects	4	16	6	22
Other invertebrates	0	0	4	0
Pike (young)	0	72	0	0
Other fishes	35	17	6	12
Other vertebrates	0	0	1	6
Plankton[3]	-	-	84	48
Other organic material	6	2	6	4

[1]Data from Kennedy and Sprules, 1967.

[2]Percentages total more than 100% since many stomachs contained more than one type of food item.

[3]Kennedy and Sprules categorized plankton as "other organic material" since it appeared relatively infrequently in stomachs they examined.

occurred in a high percentage of stomachs in 1971, but also made up a large volume of the food taken. No information is available on the abundance of crustacean zooplankton in the 1940's, but it is known that this group was very abundant in the Delta waters in 1971. It would appear that goldeye will utilize small food items such as crustaceans if small fishes are not available. Small fishes other than goldeye and walleye were relatively scarce in the tow net samples in 1971. Some shiners (Notropis sp.) and ninespine sticklebacks were taken, but no small pike were found. This probably reflects a low number of other small fishes.

The growth curve for goldeye collected in 1971 was compared with those calculated from samples collected by other investigators in 1949 and 1954 (Fig. 2). In 1971 fish of all ages were heavier than fish of the same ages in previous years. Older fish (9 and 10 years) caught in 1971 were similar in length to their counterparts in earlier years. Younger fish were considerably longer in the 1971 sample. Year classes of fish born in 1963 and more recently have experienced better growth, both in length and weight. Year classes borne in 1961 and 1962 display only greater weight than fish of similar age in earlier samples. This increased growth in recent years may be related to a decreased abundance of adult goldeye since 1963 and 1966 (Table 1).

AGE COMPOSITION AND YEAR CLASS ABUNDANCE

The age compositions of the 1954 and 1971 goldeye samples offer some evidence of changes in the age structure of the goldeye populations in the Peace-Athabasca Delta over a period of years (Table 2). Schultz (1955) states that goldeye samples collected in 1949 showed that 9- and 10-year-old fish made up approximately 85 percent of the total commercial catch. Similar samples in 1954 showed 8- and 9-year-old fish as the most abundant age groups, with 8-, 9-, and 10-year-old fish making up approximately 94 percent of the catch. In 1971, the dominant age group was 7-year-old fish and the 8-, 9-, and 10-year-old fish made up only 32 percent of the total sample. Year classes of goldeye born in 1961, 1962, and 1963 are not strongly represented in the present populations, although fish of similar ages were abundant in earlier years and were the mainstay of the commercial fishery in those years.

In the period from 1956 to 1963 an intensive commercial fishery for goldeye operated in the Delta area, producing some 3/4 million pounds of this species. It would appear that the removal of large numbers of adult fish in those years so depleted the brood stock that a number of weak year classes of goldeye were produced immediately prior to 1963. The abundant (50.8 percent) 7-year-old fish appearing in the 1971 sample were hatched in 1964, a year when extremely high water levels prevailed in the Delta area and the commercial fishery produced less than 1500 pounds of goldeye. Natural reproduction by the remaining adult stock in that year apparently produced a successful year class.

The 1963 class (8-year-old fish) was the second most abundant (28.0 percent) group in the 1971 sample. The 1965 year class (6-year-old fish) made up a rather small proportion (16.8 percent) of this catch. The latter age group was of a size that should have been caught readily in the sampling program; therefore, it is postulated that their scarcity reflects a weak year class in the present goldeye population of the Delta. No data are available at this time to suggest what reproductive success may have been achieved in the late 1960's.

The age composition of the goldeye run which entered the Delta in 1971 suggests the presence of an adequate brood stock of adult fish to provide good natural reproduction if favorable habitat conditions occur each spring and summer in the Delta area. The water regime which prevailed in 1971 appears to have been favorable for reproductive success.

SUMMER AND FALL MIGRATIONS OF GOLDEYE

The shallow waters of the Delta, particularly Lake Claire, Mamawi Lake, Prairie River, and perhaps the river channels associated with the Chenal des Quatre Fourches, tend to stagnate under winter ice cover. Most fish species are unable to survive under these unfavorable habitat conditions when dissolved oxygen levels decline or become totally depleted. Adult goldeye have been reported to migrate out of these shallow waters in the late summer, supposedly returning to the Peace River via the Chenal des Quatre Fourches.

Gill net sampling in the Prairie River during midsummer revealed

a pronounced movement of adult goldeye eastward in the Prairie River in late July and August. Domestic fishermen in the Quatre Fourches area confirmed an increase in numbers of goldeye in that area during the same period. Water currents in the Prairie River at that time were predominantly easterly, although the flow had been westerly into Lake Claire earlier in the summer. Additional gill netting in the Prairie River and the Birch River during October took no adult goldeye. The fishermen at Quatre Fourches also reported a lack of goldeye although other species were being taken. These data support the generally held view that there is a pronounced run of adult goldeye out of the Delta area back to the Peace River. In 1971 this run started in late July and had been completed by October.

Studies of changes in the abundance of young-of-the-year goldeye in different parts of the Delta region during the summer and fall indicate that emigration of young goldeye started in late July. By early October young goldeye were abundant in the Chenal des Quatre Fourches where they had been absent during the summer. They were most plentiful towards the Peace River. At the same time, young goldeye were still present in the Prairie River. By late October young goldeye were much less abundant in the Chenal des Fourches and again their numbers were greater towards the Peace River. Some were taken in the Peace River near the junction with Chenal des Quatre Fourches. Young goldeye were still present in the Prairie River and one was collected in the Birch River on October 31.

In November, after a water control structure had been installed

in the west channel at Quatre Fourches, young goldeye were found congregating behind the dam. Their size was considerably smaller than that of samples taken in October; and it is postulated that this run of young goldeye originated from tributary waters rather than from the main Lake Claire, Prairie River, Mamawi Lake complex.

Thus young goldeye in 1971 displayed a similar pattern of emigration from the shallow Delta waters to the Peace River as that noted for the adult goldeye. The migration occurred over a longer period of time with some of the young becoming marooned behind the Quatre Fourches dam in November.

WINTER POPULATIONS OF GOLDEYE

Gill net sampling under the ice at a number of stations in the Delta during the winter of 1971-72 has revealed that very few adult goldeye remained in the shallow Delta waters after freeze-up. However, 17 small goldeye were caught in the lower reaches of the Birch River in January. These were fish approaching two years of age, that is, members of the 1970 year class. A very few young fish of this year class were also taken in the summer sampling program for small fishes. The presence of this age group indicates that adult goldeye were in the Delta area in the spring of 1970 and produced some offspring. There is insufficient data to make an estimate of the size of this year class.

It is possible these young goldeye spent the winter of 1970-71 in the Birch River and others may have overwintered there during

1971-72.

Trappers in the past have taken adult goldeye in the Birch River during the early winter. Goldeye associated with the Birch River may be a separate stock of this species, or they may be part of the general population which ascends the river each spring and occasionally fails to make the outward migration before freeze-up.

A report to the Regional Supervisor of Indian Agencies at Edmonton in July, 1956, contains the following observations:

> "Since the 1954 fishery, Indian fishermen and Park wardens have netted substantial numbers of goldeye in fall dog-food fishing at the mouth of Birch River. In addition, it is reported that literally thousands of goldeyes were 'frozen-out' and perished during freeze-up when water levels dropped. Thousands of goldeyes were found along the banks of Birch River."

Apparently, low water conditions in the past have resulted in winter killing of goldeye in the Birch River. Field records on water quality for the Birch River show severe depletion of dissolved oxygen at stations on the River in both winters. Such levels of dissolved oxygen are not considered compatible with survival of fish; if any did survive, it must have been in localized areas where inflowing springs or groundwater seepages are maintaining higher levels of oxygen in the river water.

In late April of 1972 adult goldeye appeared in the marginal

waters below the Quatre Fourches dam before breakup. Goldeye disappeared from the area in early May, and local fishermen caught only a few suckers and pike up to May 9.

Water levels rose gradually in this area and on May 3 overtopped the dam and started flowing into Mamawi Lake. This inward flow continued for the next week as the Peace River water backed into the Delta via Chenal des Quatre Fourches. Other observers report that flooding Peace River waters also backed into Baril and Claire Rivers at this time, putting additional water into the Delta and providing another possible inward migration route for fish.

On May 10 the direction of water flow reversed at the Quatre Fourches under wind influence, and water started flowing out of the Delta. On May 16 work started on increasing the height of the dam to stop the outflow of water. By May 21 the dam modification was completed and water no longer flowed out of the Delta. A simple wooden fishway was placed in the dam on May 22, but differences in water levels prevented its proper function. The fishway was replaced with a trench on the same day, but an approximate three-foot head of water generated such current and turbulence in the short trench that adult fish did not ascend it. The trench was modified to reduce the current but it was not used by fish. On May 29 another trench was constructed adjacent to the island in the dam. Fish moved through this trench. The difference in water levels above and below the dam at this time was approximately 1.5 feet, and the current induced by this head of water did not prevent the passage of fish.

Adult goldeye reappeared in the Quatre Fourches area on May 10. During the remainder of May a gill net sampling program above and below the dam produced over 1,200 goldeye of which 979 were tagged. Pike and walleye were abundant in the run. Goldeye catches peaked between May 19 and May 23, about two weeks later than in 1971. Fifteen of the tagged fish were recaptured but only one (tagged on May 15 and recaptured on May 24) had moved over the dam. A local fisherman caught a tagged fish in the Prairie River on May 24, by which time goldeye were abundant in that area.

None of the goldeye caught up to May 25 were in spawning condition. Spawning seemed to be imminent in some goldeye on May 28. In 1971 the goldeye had completed spawning by May 20 under an earlier breakup and warmer weather.

It is tentatively concluded that a substantial run of goldeye entered the Quatre Fourches area around mid-May of 1972 and moved on to the interior of the Delta before the dam was raised to maintain water levels in the Delta. Spawning success of this run will be assessed during the summer. Initial efforts to provide a passageway for fish over the modified dam were not successful. Some success was finally achieved and suggests that current velocity will be a critical factor in the design of an effective fishway for goldeye.

SUMMARY

A substantial run of adult goldeye entered the Lake Claire - Mamawi Lake area of the Delta from the Peace River via the Chenal des Quatre Fourches in early May of 1971. The size range of these fish was similar to that of spawning runs observed in 1954. The average age of the 1971 spawning run was considerably younger than that in 1954. Six-, seven-, and eight-year-old goldeye made up over 95 percent of the catch in 1971, whereas in 1954, 94 percent of the catch consisted of eight-, nine-, and ten-year-old fish. The 1964 year class was the most abundant group in the 1971 run. All goldeye were mature except one male fish.

Spawning started early and was completed by May 20. Spawning was widespread from the Quatre Fourches to Lake Claire and possibly as far as the Birch River. Natural reproduction was successful and many young-of-the-year goldeye were found in the Delta during the summer. They were most numerous in Lake Claire and the Prairie River. Young walleye were also found in the Delta but occurred more abundantly in Mamawi Lake and the Quatre Fourches area. Food organisms for young fish were abundant, and the young goldeye displayed excellent growth.

Adult and young goldeye fed on similar food organisms, with crustacean zooplankters and corixid insects forming the bulk of their diet. Growth rates of adult goldeye in the 1971 samples were better than those described for Lake Claire populations in 1954 and the 1940's.

Both young and adult goldeye started migrating out of the shallow Delta waters in late July. By mid-October few adult goldeye remained in those waters. Young goldeye were still present in the Prairie River and the Birch River in late October. In November more young goldeye appeared behind the new dam at Quatre Fourches. The changing distribution pattern of goldeye in the Delta, during the summer and fall, confirms that they tend to return to the Peace River from the shallow Delta waters via the Chenal des Quatre Fourches.

Winter gill net sampling in the Delta took no adult goldeye. A few young goldeye were found in the lower Birch River. Their age indicated that these fish were hatched in 1970, giving evidence that some natural reproduction occurred in the Delta waters that year. Reports from earlier years indicate that goldeye do stay in the Birch River in some winters and heavy mortalities have occurred.

The 1971 water regime in the Peace-Athabasca Delta was suitable for goldeye reproduction. Early spring water levels of 684.0 feet above sea level at Quatre Fourches and 685.0 in the Prairie River and Lake Claire, produced by the backwater effect of flooding in the lower Peace River, stimulated adult goldeye to enter the Delta area for spawning. These water levels should be considered as the minimum required to assure conditions favorable for the natural reproduction of goldeye in the Delta.

Water levels rose slowly during the early summer and started to decline in late July. The declining water levels and possibly

other environmental factors stimulate both young and adult goldeye to migrate out of the Delta. Any proposals for water control in the Delta should use the 1971 water regime as a guideline for goldeye requirements. Water control structures need fishways that will permit movement of goldeye seasonally, as revealed by the 1971 studies.

Other species of fish, particularly pike and walleye, also spawn in the Delta waters. These species spawn earlier than goldeye and allowance should be made for this in any plans for water controls.

In the spring of 1972 inward migration of goldeye, pike, walleye, and other species was adversely influenced by the experimental water control structure at Quatre Fourches. Improvised fish passages constructed over the dam were not entirely successful in lessening this effect. A substantial number of fish did gain entry to the Lake Claire - Mamawi Lake area through the Quatre Fourches channels during a short period in early May, when floodwaters overtopped the dam. Access through the Baril and Claire Rivers may also have occurred during this period of high water. Continuing study will confirm whether goldeye spawned successfully in the Delta area. Any plans for permanent water control structures with fish passage facilities must take cognizance of the role that normal water regimes play in directing and controlling spawning runs of fish to the Delta during spring floods. Current velocities may be critical.

ACKNOWLEDGEMENTS

The study could not have been completed without the enthusiastic support of the Peace-Athabasca Delta Project staff and particularly the untiring efforts of Mr. Pat Cruickshank at Fort Chipewyan to facilitate the field operations. The advice and assistance of G. Lister of the National and Historic Parks Branch and Mr. H. Wylie of the Indian Affairs Branch at Fort Chipewyan was greatly appreciated. The following persons contributed importantly to the field studies and the laboratory analyses of the data: A. C. Colbeck, D. B. Donald, D. A. Fernet, F. Ladouceur, D. W. Mayhood, R. McKay, P. D. van der Giessen, and D. Whitehead. Their excellent field and laboratory work made the study a success. Staff members of other agencies co-operating in the Delta studies were most helpful with suggestions and criticisms, and the benefits of these encounters are hereby acknowledged.

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SECTION G

INVESTIGATION OF LAKE TROUT SPAWNING IN LAKE ATHABASCA, 1971

by

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October, 1971

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INTRODUCTION

Recent changes in the water level regime of Lake Athabasca have called into question possible detrimental effects on the success of lake trout reproduction. A water level decrease could possibly be of particular importance in the narrow portion of the Lake east of Poplar Point, (Fig. 1) where the seiche effect produced by autumn winds might be most pronounced. The present study pursued the following objectives:

(1) To record lake trout spawning times and distribution of spawning areas.

(2) To observe the effect of wind-induced currents and temperatures on trout spawning activity.

(3) To observe underwater the depth distribution of spawn and to examine whether winter decreases in lake level in the eastern portion of Lake Athabasca are great enough to harm these eggs.

(4) To tag lake trout; to record their movements.

The field program started on September 10 and continued to October 5. Personnel involved in various aspects of the work included: R. P. Johnson, L. M. Royer, M. L. Scobie, B. P. Bergman, A. R. Cotter, and F. Powder.

METHODS

Interviews with fishermen and sampling of the commercial catch were carried out at the Co-op Fishery processing plant at Crackingstone Point (Fig. 1). Mr. Roy Schlader, the camp manager, supplied accommodation and useful information in this phase of the work. The location of trout catches and sexual maturation of female trout were reccrded here from September 16-23.

A field camp was set up at Adair Bay on the north shore, north of Poplar Point, from September 13 to October 5 (Fig. 2). Gill nets of 1- to 3-inch stretched mesh were used to capture trout on spawning substrate within a 4-mile radius of the camp. Fish in good condition were tagged with numbered Floy dart streamer tags inserted at the base of the dorsal fin. Daily surface water temperatures and wind velocities were observed and a rough lake level check was kept. Examination of suitable spawning substrate for trout eggs was made here by a SCUBA diver, and a glass-bottomed viewing box was used in other areas.

FIG. 1 Lake Athabasca, showing location of lake trout study area

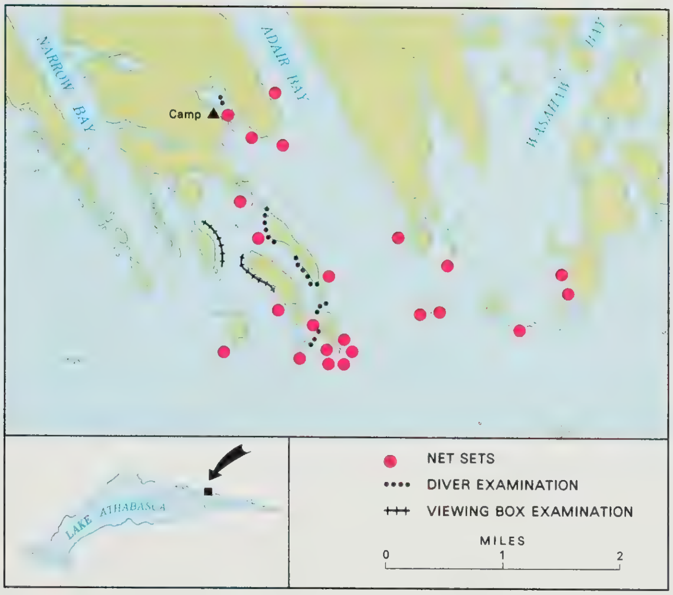

FIG. 2 Adair Bay locale showing areas of net sets and areas searched for eggs

OBSERVATIONS

SPAWNING AREAS

Interviews with knowledgeable fishermen and others indicate that trout spawning areas are widespread over the lake, with a strong suggestion that areas of concentration have changed over a period of time. In the early years of the fishery, good catches of spawners were made as far east as Grease Bay, but these catches rapidly diminished. Spawning is reported to eccur along the entire north shore at least as far west as Maurice Point. A heavy concentration of uniformly small spawning trout (averaging 2.5 lb) has been harvested from the bay between Metos Bay and Deadcree Point. Ripe trout have been taken on several rocky shoals along the south shore.

While the shoreline north of Póplar Point has been reported as a favored spawning area in past years, there is a conviction among many fishermen that the preferred spawning grounds are now the Maurice Point - Lobstick Island area. The paucity of trout in the survey nets set in the Adair Bay area and the heavy commercial catches in the Maurice Point - Lobstick Island area support this suggestion.

The commercial trout catch by the Crackingstone fishermen from September 16-22 was concentrated in three locations. The largest part of the catch (65 percent) came from the Lobstick Island - Maurice Point - Beartooth Island area. Some 15 percent was produced near Crackingstone Point and 20 percent near Oldman Island. Four notably large (47-60 lb) female trout were taken

near Long Island in this sampling. This area is termed the 'old-folks home' for trout by some of the experienced fishermen.

MATURATION OF FEMALES

Examination of the gonad condition of 380 female trout in the commercial catch between Oldman Island and Maurice Point is summarized below:

	Condition of Gonad				
Date	Green	Near-ripe	Ripe	Spawned out	Total
Sept. 16	7	24	4	1	36
Sept. 18	3	8	2	-	13
Sept. 19	5	59	10	-	74
Sept. 20	11	109	22	6	148
Sept. 21	12	47	45	5	109

Up to September 20, 83 percent of the fish were not ripe; on September 21 about 40 percent were ripe. Only a small number of fish were spawned out. The fishery ended before major spawning had occurred.

There was a strong suggestion from the interviews with fishermen that trout in the eastern portion of the Lake spawn up to two weeks earlier than those in the western end. Data from the present study fail to clarify this point. Certainly, if much spawning took place in 1971 it was later than usual. (Spawning

reportedly was over in 1970 by September 13.)

Four fish examined from the Crackingstone catch had eggs in the ovaries which were obviously not sufficiently developed for spawning in the current season. The incidence of trout which do not spawn each year would have to be determined by examination of the catch throughout the year; Miller and Kennedy (1948) found spent, ripe, or immature females on one spawning area in Great Bear Lake, while through the year a number of mature fish, which would not spawn in the current season, were noted.

OBSERVATIONS ON PHYSICAL CONDITIONS

Surface water temperatures were about 11-12° C when the camp at Adair Bay was first set up on September 14 (Table 1). The lake cooled slowly to below 10° C on September 24 and was between 8.5-9° C when the camp was dismantled on October 4. The weather was generally windy with five calm days in the 18 days of wind measurement. Windstorms on September 24-26 and 28 and on October 1 prevented boat travel by the survey crew.

Water levels between September 17 and October 4 varied by 18 inches, with a general decline of about a foot.

GILL NET CATCHES

Gill nets were set at 23 locations (Fig. 2) within a four-mile radius of the Adair Bay camp from September 16 to October 4 inclusive. A total of 764 fish were captured (Table 2). Among these were 83 trout, a very meager catch for a 'preferred spawning area.' No trout were caught during the first four days

Table 1. Physical conditions at Adair Bay, Lake Athabasca, 1971.

Date	Surface water temperature (°C)			Wind velocity (M.P.H.)			Water level (inches + or -)		
	8 am	12 n	5 pm	8 am	12 n	5 pm	8 am	12 n	5 pm
Sept. 14	-	10.8	-	-	-	-	-	-	-
15	-	11.8	10.8	-	-	-	-	-	-
16	10.2	11.2	11.4	0-2	0-7	0-5	-	-	-2
17	11.0	11.6	10.6	0-15	10-25	0-10	+2.5	+1.5	0
18	11.0	11.9	10.8	0	5-15	5-20	0	-2	-1
19	10.2	10.8	10.0	0-10	3-20	10-25	- .5	-1	-5
20	9.9	10.2	10.1	0	0	0	-4.5	-4.5	-4.5
21	10.0	10.9	10.2	12-15	5-8	2-6	-4	-3.5	-3.5
22	10.2	10.8	10.1	0	1-3	0	-4.5	-6.5	-6.5
23	10.4	11.0	10.2	0	1-3	0	-6.5	-6.5	-7.5
24	9.0	10.0	9.3	16-30	18-30	21-30	-9.5	-11	-12
25	9.4	9.5	9.3	25-35	25-35	25-35	-15	-15	-15.5
26	8.6	8.9	8.6	18-25	14-20	5-7	-11	-10	-10
27	8.3	8.8	8.0	0	0	0	-9	-9	-8
28	8.6	9.0	8.9	10-12	10-15	9-13	-5.5	-6	-5.5
29	8.8	8.8	8.2	9-15	12-15	3-5	-7	-8.5	-10
30	8.2	9.1	8.6	6-10	0	6-12	-8.5	-10	-11
Oct. 1	8.4	8.8	8.2	21-30	12-15	10-12	-10.5	-11.5	-13
2	8.6	9.6	9.4	0-5	0	0	-13	-11	-13
3	8.8	8.8	8.8	15-18	12-15	16-20	-10	-10.5	-12.5
4	8.4	9.0	9.0	0	2-5	0	-13.5	-12	-13

Table 2. Gill net catches near Adair Bay, Lake Athabasca, 1971.

Date	Yardage of net lifted	Depth (ft.)	Lake trout	White-fish	Cisco	Pike	Suck-ers	Gray-ling	Bur-bot	Wall-eye	All sp.
Sept. 16	300	10-40	-	22	-	1	2	-	-	-	25
17	300	10-40	-	9	-	3	-	-	-	-	12
18	300	12-45	-	56	1	6	13	-	-	-	76
19	200	10-90	-	38	145	4	29	-	-	-	216
20	300	10-70	8	14	7	18	2	1	2	-	52
21	400	10-70	7	32	9	13	2	-	1	-	64
22	400	10-40	7	39	5	9	1	-	2	-	63
23	300	5-36	20	26	3	10	1	-	-	1	61
27	300	8-25	22	24	-	16	-	6	1	-	69
29	200	8-25	11	2	-	-	-	-	1	-	14
30	150	6-90	7	12	10	13	5	-	-	-	47
Oct. 2	175	3-70	-	18	3	16	-	2	1	-	40
3	100	3-20	-	6	-	9	4	-	-	-	19
4	75	8-25	1	5	-	-	-	-	-	-	6
Totals	3,400		83	303	183	118	59	9	8	1	764

of fishing. A few were caught on following days, reaching 20 individuals on September 23. A three-day windstorm followed; when it was again possible to lift nets on September 27, a catch of 22 trout was made, most of which were in lively condition. The catch then dropped off rapidly and after September 30 only one trout was captured.

Condition of 23 female trout examined during the gill netting is found below:

Date	No. of fish	Condition
Sept. 20	2	Green
Sept. 22	3	Near-ripe
Sept. 23	8	Near-ripe
Sept. 27	4	Ripe
Sept. 29	4	Ripe
Sept. 30	2	Ripe

It appears that the complete maturation of eggs occurred simultaneously with the three-day storm of September 24-26.

Forty-seven trout were tagged and released, with tags labeled "Ret. Sask. Fish. Br. DNR." Most of these trout were estimated to weigh from 3-7 lb, with a few over 10 lb, and one about 25 lb. Tag numbers and the associated date of tagging are listed below:

Date tagged	Tag numbers
Sept. 20	11100-11103
Sept. 21	11104-11108
Sept. 22	11109-11115
Sept. 23	11116-11127
Sept. 27	11128-11142
Sept. 29	11143-11145
Oct. 4	11146

THE SEARCH FOR TROUT EGGS

On September 30, wind conditions were calm enough to allow a careful underwater search for trout eggs on seemingly suitable rock rubble in areas where trout had been captured (Fig. 2). Such substrate was found down to depths between 6 and 12 feet; below this, sand was encountered. Although a considerable stretch of shoreline was examined (approximately 1,500 yards), and a search made in crevasses among the rocks, no eggs were seen.

A less-detailed search for eggs using a glass-bottomed viewing box was made on October 2 and 3. Depths from 2.5 to 6 feet were scanned along the shore of two islands (Fig. 2), but again no eggs were seen.

DISCUSSION AND CONCLUSIONS

The variety of spawning areas known to the commercial fishermen, and the opinion that there are different spawning periods in various areas of the lake, suggest the existence of several physiological races of trout in Lake Athabasca. The reported stock of small trout spawning between Metos Bay and Deadcree Point may be one of these. The literature on lake trout reveals that two or more populations can inhabit the same lake (Hubbs, 1930; Dymond, 1926). Eschmeyer (1964) indicates that as many as a dozen subpopulations are believed to exist in Lake Superior.

Three possibilities exist as to the time of spawning in the Adair Bay area. Spawning may have occurred before the camp was set up; undetected spawning may have occurred while the survey crew was present; or spawning may not have occurred until the camp was dismantled.

If spawning had already taken place before the Adair Bay camp was established, the eggs were completely removed by some unknown factor. This seems improbable. The trout which were first caught in the area were not ripe. The local helper stated that eggs laid in this area in other years in shallow (1.5 ft) water were easily seen.

DeRoche (1969) found that one or two days of strong winds provided the stimulus needed to initiate major spawning. Windy weather generally prevailed at Adair Bay while the survey crew was there (Table 2). The storm of September 24-26 seemed to bring the females to a ripe condition. However, the presence of

ripe fish, with none observed to be spawned out on days following the storm, and the absence of eggs four days later, indicate that spawning had not been extensive up to October 4.

Since surface water temperatures (Table 1) were below those at which trout spawn (11-9° C) when the Adair Bay camp was dismantled, it is conceivable that most of these fish might not spawn in 1971. Rawson (1961) reports that in Lac La Ronge the trout arrive on the spawning reefs at water temperatures of 13° C. Water temperatures at the onset of spawning are near 11° C and 9-10° C when spawning ends. Spawning in Lac La Ronge appears to take place in a rather short period, usually within the first week of October.

Evidence of extensive suitable trout spawning grounds over widely separated areas of Lake Athabasca appears to minimize any detrimental effect of seiches in the restricted Poplar Point area. More serious questions seem to be whether year-class recruitment is only sporadically successful, what proportion of the mature fish spawn annually, and the fate of eggs spawned in very shallow water. The past history of an abundant trout population indicates that spawning habits have been adapted to overcome these difficulties under past conditions.

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SECTION H

A SURVEY OF THE PLANKTON AND BOTTOM INVERTEBRATES OF THE PEACE-ATHABASCA DELTA REGION

by

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INTRODUCTION

During the summer of 1971, a survey of the plankton and bottom fauna present in the Peace-Athabasca Delta was carried out under the sponsorship of the Peace-Athabasca Delta Project and the University of Alberta. The objectives of the survey were to obtain needed background information on the plankton and bottom fauna found in the Delta and to compare aquatic invertebrate fauna in different regions of the Delta with respect to available food for fish. In addition, the background data provided by this survey will be useful for comparing information from future investigations to determine any drastic changes that may take place. Since no previous limnological work has been done in the Delta region, the present report contains only information regarding diversity and biomass differences between sample sites during a portion of the year and does not take into account seasonal or annual fluctuations.

As part of a larger ecological study of the Delta, this survey was especially concerned with the possible detrimental effect of lowered water levels on aquatic life in shallow lakes and streams of the Delta. It was speculated that low waters, with consequent freezing to the bottom, in most of the Delta might seriously reduce bottom fauna populations and affect certain major zooplankton species. Since zooplankton and bottom organisms are major sources of food for goldeye (*Hiodon alosoides*) adults and fry, as well as other species of fish, there was concern that reduced populations of plankton and bottom organisms would result in a significantly smaller fish

crop and/or growth rate. Concern was also shown for the lack of significant seasonal flooding that has occurred since the filling of Williston Lake Reservoir on the Peace River. This flooding used to have the effect of recharging the normally isolated shallow surrounding lakes with nutrients and organic detritus.

METHODS

PLANKTON

Plankton sampling sites were predetermined on a map or by investigations in the field. In general, sampling covered as much of the Delta as possible within the time limits (Fig. 1). However, only selected sites were analyzed for species composition, while biomass was determined for all sites. Therefore, the species list is only tentative. Capture of plankton involved a Model 40 Wildlife Supply Wisconsin-type plankton net, #20 mesh. When towing the net several inches beneath the surface at a standard velocity of 1 metre per second for a period of 10 seconds, approximately 100 litres of water were filtered at any one time. The plankton net was towed in the above-mentioned position at all sites because of shallow water conditions in most areas and in order to maintain uniform sampling conditions. It is possible that maximum zooplankton concentrations were missed in some cases, but the relative amounts should remain constant throughout the water column due to heavy wind and/or current conditions that occurred during the sampling period. Periodic vertical or diagonal hauls did not show any significant differences when put on a per litre basis. One horizontal haul was made at each site; the samples were washed out and preserved in a 10 per cent formalin solution in 16 dram plastic vials.

Transportation involved using a powered freighter canoe for most of the sampling. However, isolated locations were approached by

helicopter or float-plane.

Organisms were identified according to Edmondson (1959) and Pennak (1963). The relative abundance of each group, genus and/or species, applies within individual samples and no attempt was made to compare the above between samples. Plankton volume was measured by allowing all organisms to settle in calibrated centrifuge tubes for a comparison between samples.

Phytoplankton was not looked at in any detail. Net plankton were only noted where they occurred in large numbers, such as the Canadian Shield lakes at sample sites 44 and 45 (Fig. 1).

Crustacean zooplankters were observed in the most detail, having been the most important plankters in terms of a food source for fish.

Rotifers were only noted where there was an extreme abundance of a particular species. Therefore, they were not analyzed consistently in all samples. They should be looked at in greater detail in the future.

BOTTOM INVERTEBRATES

Replicate bottom samples were taken at each site with a 6-inch Eckman dredge. These were then cleaned with a 0.6 mm sieve and later sorted under a dissecting microscope. After removing excess water from the animals, they were weighed to the nearest milligram in the laboratory. Identification was made according to Edmondson (1959).

FIG. 1 Limnological Survey Sampling Sites, 1971

RESULTS AND DISCUSSION

PLANKTON

Analyses of the samples indicate that crustacean zooplankton organisms were very abundant, while net phytoplankton cells were scarce in the Delta region (Table 1). The zooplankton diversity, in terms of numbers of species, is not exceptionally great in this region; but the samples, using volume determinations, showed relatively high biomass of the larger species such as *Daphnia magna*, *D. pulex*, and *Epischura nevadensis* (Tables 1 and 2). The mean biomass was greatest in Lake Claire, followed by Richardson Lake, the Prairie River complex, and Mamawi Lake, decreasing to minimum values in the Riviere des Rochers and Lake Athabasca regions (Table 2, Fig. 1). The mean value for the Canadian Shield lakes (8.4 cm^3) is misleading since inspection confirmed that these samples contained large quantities of phytoplankton (*Anabaena*, *Gloeotrichia*, and *Aphanizomenon*) and very little zooplankton.

The existence of relatively high numbers of large zooplankton species was surprising since it is usually assumed that these animals are directly dependent upon phytoplankton for food. The apparent scarcity of phytoplankton would mean that those organisms have to rely heavily upon another food source. Evidence suggesting low phytoplankton production in the Delta, at least at certain times, was the high turbidity factor due to wind mixing in the shallow lakes and/or the inflow of allochthonous materials from the river systems. The Secchi disc

Table 1. Plankton types: abundance within each sample site collection (5=very abundant, 4=abundant, 3=common, 2=present, 1=rare).

Sample site nos. / Phytoplankton	8	21	22	25 a	25 b	27	32	23	2	4	6	7	38	12	42	43	46	34	35	44	45
Dinophyceae																					
Ceratium sp.																			5		
Myxophyceae																					
Anabaena sp.								1					2							4	5
Gloeotrichia sp.													5								4
Aphanizomenon sp.																					3
Zooplankton																					
Rotifera																					
Keratella canadensis	4	2												3							
Philodina sp.									5												
Crustacea																O					
Cladocera																R					
Alona rectangula																G			1		
Bosmina longirostris	2	1	2	1					1		1	3		1		A	1	3		2-3	
Ceriodaphnia sp.																N	1				
Daphnia galeata mendotae											2					I	1				
Daphnia magna			4	4	3	5				1						C					
Daphnia pulex		1	5	5	5	4	5	1		3	2			1	3		2		5		
Daphnia retrocurva	5	4	3	3	4		2	1	3	3	5	5		5		D		2			
Diaphanosoma leuchten-bergianum	1		1						1		1	2			1	E T	1		2		
Holopedium gibberum																R					3
Leptodora kindti		1	2		3		1		5							I	1				3
Simocephalus vetulus										1						T					
Copepoda																U					
Cyclops bicuspidatus thomasi	3	2							2		4	1		4		S					
Cyclops vernalis		3		1	2									5							
Cyclops sp. (copepodites)					4			1					1				3	5	3	2	2
Mesocyclops edax																			2		—

(Continued on next page.)

Table 1. Continued.

Phytoplankton / Sample site nos.	8	21	22	25 a	25 b	27	32	23	2	4	6	7	38	12	42	43	46	34	35	44	45
Diaptomus sicilis	2	2	3	2	2		2		4		5			2			1				
Diaptomus oregonensis																			3		
Diaptomus sp. (copepodites)																	3				1
Epischura nevadensis	4	5	4	3	4	2	2	1	5			5		3			3	5	2		
Harpacticoid copepods				1																	
Nauplii	4			1			1					5					2-3				
Ostracoda		1		1																	
Arachnida																					
Acarina																					2
Insecta																					
Chaoborus sp.											1										

Table 2. Zooplankton volumes (cm^3 from the filtration of 100 litres of water).

	Sample Site No.	cm^3	Mean
Lake Claire	7	2.8	
	8	6.3	
	20	4	
	21	1	
	22	5.5	
	25 a	4	4.6
	b	16.5	
	27	1.6	
	30	2	
	31	4.6	
	32	1.8	
Birch River	23	2.5	2.5
Prairie River complex	1	6	
	2	2	
	4	1.5	
	5	2.5	3.3
	6	3	
	9	1	
	24	7	
Mamawi Lake	3	2.5	2.5
Quatre Fourches River	12	2.4	
	39	0.4	1.9
Fort Chipewyan-Lake Athabasca	11	0.8	
	33	0.4	0.6
Lake Athabasca	34	0.55	
	35	0.28	0.4
Canadian Shield lakes	44	4.2	
	45 (1)	7.0	8.4
	(2)	14.0	(mostly phytoplankton)
Riviere des Rochers	41	0.6	
	42	0.5	0.6
	43	0.7	
Richardson Lake	46	0.4	
	47	7.0	3.7
Mamawi Creek	38	0.88	0.9

readings of the Delta lakes never exceeded 5-10 centimetres; this would tend to limit phytoplankton production. In contrast, the Canadian Shield lakes showed Secchi disc readings of over 2 metres (sites 44 and 45, Fig. 1). These Shield lakes had large standing crops of phytoplankton and presumably much greater primary production. However, the effect of cropping by zooplankton in the Delta lakes has not been considered in any detail; but it is unlikely that this is the major cause for the scarcity of phytoplankton, for the reasons given above. One possible food source is still being investigated by Dr. M. Hickman, Botany Department, University of Alberta; that consists of epipelic algae which would only be found in large numbers around the margins of lakes where solar radiation can penetrate to the bottom.

Assuming the preceding conditions, the zooplankton must be getting the major portion of their food from another source. Nauwerck (1963), in a study of zooplankton-phytoplankton relationships in Lake Erken, Sweden, noted that the primary production of phytoplankton was not sufficient to sustain large zooplankton populations. He suggested that a large portion of the food must come from organic detritus and bacteria. Further support is given by Straskraba (1966) who states that a heavy flow of water into the Slapy Reservoir, carrying a large amount of allochthonous matter, may be responsible for a high zooplankton standing crop. It is felt that this situation prevails in the Peace-Athabasca Delta. The heavy inflow of water into the Delta at certain times brings in large quantities of

organic detritus which is acted upon by bacteria, forming an organic detritus-bacteria complex. The wind action, either by direct or seiche movement, ensures that this material is constantly suspended in the water column and therefore readily available for filter feeding zooplankton organisms. This may in part explain the high zooplankton populations. Under these conditions, food may never become a limiting factor for the production of zooplankton.

The heavy dependency of fish on zooplankton for food was rather surprising. During the summer, an opportunity arose to observe the stomach contents of fish captured for the goldeye study conducted by Dave Fernet of Saskatoon. A high percentage (up to 60%) of the stomach contents of adult goldeye proved to be zooplankton. The remainder was composed of corixids and to a lesser extent, insect larvae and minnows. Another fish study conducted at Richardson Lake by Karl Dietz, Alberta Department of Lands and Forests, Fish and Wildlife Division, revealed similar results with walleyes (Stizostedion vitreum vitreum); a large portion of the diet was zooplankton. Analysis of the stomach contents of some walleye fry showed that the zooplankton content was very high (greater than 90% in most cases). The utilization of zooplankton by young fish is well established, but the high incidence of zooplankton in the stomach contents of adult fish is unique as far as goldeye are concerned. The gillrakers of goldeye are short and widely spaced, not conducive to plankton feeding. McPhail and Lindsey (1970) state that these fish utilize mostly aquatic and terrestrial insects with some of

the larger goldeye eating smaller fish and mice. It is also stated that goldeyes frequent very turbid waters and feed mainly on the surface at night in this geographical region. They suggest that the eyes may be adapted for night vision as well as for vision in turbid waters. Therefore, zooplankton predation would be a visual process and goldeye would select for the larger species. This means that the existence of high numbers of large zooplankton species (i.e., *Daphnia magna*, *Daphnia pulex*, and *Epischura nevadensis*) may be an unusual situation in the Delta region. Brooks and Dodson (1965) and Dodson (1970) have shown that when zooplankton-feeding fish are present, there is a size selection for the larger species with these larger organisms ultimately disappearing from the plankton. Why the large zooplankton species have not been eliminated from the Delta is not clear. It may be that visual predation by the fish, coupled with limited visibility due to high turbidity, allow enough organisms to escape for reproduction, since the gillraker morphology of the adult fish apparently is not conducive to filter feeding. Another possibility is that predation upon zooplankton is relieved by the migration of adult fish out of the Lake Claire - Mamawi Lake area in late July (Kooyman, 1972). However, it does not seem likely that predation would decrease, but rather increase in the Lake Claire - Mamawi Lake area due to the number of fry present during the summer. Kooyman (1972) and personal observations have confirmed that the above-mentioned area is important as a nursery for goldeye. Other regions of the Delta are apparently of equal importance as nurseries for other fish, such as walleye. A final possibility for the existence of

large zooplankton species in abundance is that the reproductive rate exceeds that of the predation rate. This would only be possible during the entire summer period if there was an unlimited food supply as previously suggested. With the periodic replenishment of organic detritus, coupled with continual suspension of food particles in the water column, it is possible that the fish cannot crop the zooplankton as fast as they reproduce. Also, development times of eggs and embryos, as well as instar duration, are regulated by temperature. The shallow Delta lakes tend to warm quickly to relatively high temperatures, thus enhancing reproduction (see Appendix). This final hypothesis, excessive food coupled with warm conditions, seems to be the most plausible explanation for the existence of high numbers of large zooplankton species. Further investigation, however, is required to substantiate this hypothesis.

Complete freezing of the Delta lakes and a portion of the west end of Lake Athabasca during the previous winter (1970-71) seemed to have little effect on plankton populations, as would be expected. Most zooplankton organisms have resistant stages, such as the ephippial eggs of Cladocera or resting stages of the Copepoda in the bottom muds. Ephippial eggs can withstand freezing and, in fact, may need alternate freezing and thawing before development starts in the spring. Also, the spring flow of water into the Delta would tend to recruit new organisms of some species.

The distribution of _Daphnia magna_ in the Delta region is

interesting. This species was found only in Lake Claire and at one station on Prairie River, possibly due to being carried out of the Lake by currents (Table 1). The only possible explanation of distribution is the chemical composition of the lake water (Table 3, from Reeder, 1971). However, since both Lake Claire and Mamawi Lake show equally high sodium, calcium, chloride, and sulfate content, as compared to Lake Athabasca, the lack of *Daphnia magna* in Mamawi Lake may be due to inadequate sampling. Reeder (1971) states that rivers and streams which drain over sedimentary rock before entering the Delta show relatively high amounts of the above chemical constituents. This is especially true of the Birch and McIvor Rivers that enter Lake Claire (Fig. 1, Table 3). It would appear that conditions, including chemical characteristics, are nearly optimum for *Daphnia magna* in Lake Claire, but not in other regions of the Delta. However, most species of zooplankton, including *Daphnia pulex* and *Epischura nevadensis*, are relatively tolerant to a wide range of salt concentrations and therefore occur in large numbers in the Delta. Critical conditions may arise if permanent dams are constructed to maintain constant water levels in Lake Claire, Mamawi Lake, or other regions of the Delta. This would tend to increase the chemical concentrations which may exceed the tolerance limits of zooplankton organisms and fish. Large increases in the sodium, calcium, chloride, and sulfate content of Delta waters could possibly eliminate some of the large crustacean zooplankters, thereby reducing fish food, or could affect the reproduction and/or physiology of the fish directly.

Table 3. Chemical properties of lake and river waters of the Peace-Athabasca Delta.[1]

Location		Lake Athabasca	Lake Claire	Mamawi Lake	Birch River	McIvor River	Prairie River	Athabasca River
pH		7.7	8.0	7.6	7.2	7.5	7.4	8.1
Conductance	(mg/1)	102	665	670	409	520	431	300
Alkalinity	(mg/1)	35.9	109	101	61.2	50.4	78.8	-
Hardness	(mg/1)	41.5	214	191	112	142	137	-
Na	(mg/1)	3.5	58.8	57.6	36.5	40.1	29.0	12.3
Ca	(mg/1)	11.6	57.7	52.8	31.7	42.5	38.0	34.1
Cl	(mg/1)	4.3	88.0	88.0	49.5	50.2	43.3	12.0
SO_4	(mg/1)	6.6	110.8	97.7	60.9	110.0	63.7	23.8

[1]Data from Reeder, 1971.

BOTTOM INVERTEBRATES

The results for each station are given in Table 4. A total of 25 families were identified. A short description of each group is as follows:

Nematoda

These could not be identified to family because the interior tissue had disintegrated. There are at least two species belonging to the Class Phasmida. They were found on the west shore of L. Claire, L. Mamawi, and L. Athabasca, and in two small adjacent lakes.

Oligochaeta

There are at least three species, all belonging to the Tubificidae. They were found at most stations.

Hirudinea

These include *Glossiphonia complanata*, *Helobdella stagnalis*, and one unidentified species. They were found primarily in the region between L. Claire and L. Mamawi.

Conchostraca

These belonged to the genus *Caenestheriella*. They were found at the north end of L. Claire and at the mouth of the Riviere des Rochers.

Table 4. Bottom invertebrates identified and weighed from replicate (2) six-inch Eckman dredge samples taken at various stations.

Group	Wet weight (milligrams) by Station & Sample										
	1-1	1-2	2-1	2-2	3-1	3-2	4-1	4-2	5-1	5-2	6-1
Nematoda											
Oligochaeta											
Tubificidae	628	1526								1	
Hirudinea											
Glossiphoniidae	14	17								*	
Conchostraca											
Cyzicidae											
Ostracoda											
Cypridae											
Amphipoda											
Gammaridae											
Ephemeroptera											
Caenidae											
Siphlonuridae											
Baetidae											
Odonata											
Agrionidae											
Hemiptera											
Corixidae			44								
Trichoptera											
Leptoceridae		25									
Molannidae											
Limnephilidae											
Coleoptera											
Dytiscidae											3
Diptera											
Chironomidae	68	97	105		10	1	70	231	25	159	344
Ceratopogonidae	1										
Tabanidae											
Hydracarina											
Pionidae											
Eylaidae											
Pelecypoda											
Sphaeriidae	193	1900	431	612		11		15		26	406
Gastropoda											
Lymnaeidae	8	214	5	18			7				
Planorbidae											
Physidae											
Valvatidae											
Total	912	3779	541	630	10	12	77	246	25	186	753

* = less than 1 mg. (Continued on next page.)

Table 4. Continued.

Group	Wet weight (milligrams) by Station & Sample								
	6-2	7-1	7-2	8-1	8-2	9-2	10-1	20-1	20-2	21-1
Nematoda										
Oligochaeta										
Tubificidae	6							*	*	
Hirudinea										
Glossiphoniidae						16				
Conchostraca										
Cyzicidae										
Ostracoda										
Cypridae										
Amphipoda										
Gammaridae							31			
Ephemeroptera										
Caenidae										
Siphlonuridae							44			
Baetidae										
Odonata										
Agrionidae										
Hemiptera										
Corixidae							16			
Trichoptera										
Leptoceridae										
Molannidae										
Limnephilidae										
Coleoptera										
Dytiscidae	6									
Diptera										
Chironomidae	274	2		1	6		43	2	7	
Ceratopogonidae										
Tabanidae										
Hydracarina										
Pionidae										
Eylaidae							8			
Pelecypoda										
Sphaeriidae	1676	7		42	10	104	33			
Gastropoda										
Lymnaeidae	48									
Planorbidae										
Physidae										
Valvatidae						7				
Total	2010	9	0	43	16	120	167	2	7	0

* = less than 1 mg. (Continued on next page.)

Table 4. Continued.

Group	Wet weight (milligrams) by Station & Sample								
	21-2	21-3	22-1	22-2	23-1	23-2	24-1	24-2	25-1
Nematoda									
Oligochaeta									
Tubificidae			*						
Hirudinea									
Glossiphoniidae									
Conchostraca									
Cyzicidae									
Ostracoda									
Cypridae		*							
Amphipoda									
Gammaridae									
Ephemeroptera									
Caenidae									
Siphlonuridae									
Baetidae									
Odonata									
Agrionidae									
Hemiptera									
Corixidae									
Trichoptera									
Leptoceridae									
Molannidae									
Limnephilidae									
Coleoptera									
Dytiscidae									
Diptera									
Chironomidae	7				*	5	64	132	1
Ceratopogonidae									
Tabanidae									
Hydracarina									
Pionidae									
Eylaidae									
Pelecypoda									
Sphaeriidae			*		712	1550	8	36	
Gastropoda									
Lymnaeidae					49	79	20	41	
Planorbidae									
Physidae									
Valvatidae									
Total	7	*	*	0	761	1634	92	209	1

* = less than 1 mg. (Continued on next page.)

Table 4. Continued.

Group	Wet weight (milligrams) by Station & Sample								
	25-2	26-1	27-1	30-1	30-2	31-1	31-2	32-1	32-2
Nematoda		2	*					3	6
Oligochaeta									
Tubificidae	*	13	1					75	99
Hirudinea									
Glossiphoniidae									
Conchostraca									
Cyzicidae									
Ostracoda									
Cypridae		3	1	*	*	*	*		
Amphipoda									
Gammaridae									
Ephemeroptera									
Caenidae									
Siphlonuridae									
Baetidae									
Odonata									
Agrionidae									
Hemiptera									
Corixidae							14	1	
Trichoptera									
Leptoceridae								*	
Molannidae									
Limnephilidae									
Coleoptera									
Dytiscidae									
Diptera									
Chironomidae	1	12		1				16	21
Ceratopogonidae						*			
Tabanidae									
Hydracarina									
Pionidae									
Eylaidae									
Pelecypoda									
Sphaeriidae	3	112							4
Gastropoda									
Lymnaeidae		3						5	
Planorbidae									
Physidae									
Valvatidae									
Total	4	145	2	1	*	*	14	100	130

* = less than 1 mg. (Continued on next page.)

Table 4. Continued.

Group	Wet weight (milligrams) by Station & Sample								
	34-1	34-2	35-1	37-1	38-1	38-2	38-3	39-1	41-2
Nematoda						*			
Oligochaeta									
Tubificidae					15	12	6		
Hirudinea									
Glossiphoniidae							2		
Conchostraca									
Cyzicidae				100					
Ostracoda									
Cypridae				1					
Amphipoda									
Gammaridae		3	5		9	6	164		21
Ephemeroptera									
Caenidae							2		
Siphlonuridae									
Baetidae									
Odonata									
Agrionidae							6		
Hemiptera									
Corixidae									
Trichoptera									
Leptoceridae						3	6		
Molannidae							5		
Limnephilidae									
Coleoptera									
Dytiscidae							7		
Diptera									
Chironomidae		3	4	3	42	114	1	4	*
Ceratopogonidae									1
Tabanidae									
Hydracarina									
Pionidae							1		
Eylaidae									
Pelecypoda									
Sphaeriidae						171	50		8
Gastropoda									
Lymnaeidae						279			
Planorbidae							6		
Physidae							34		
Valvatidae						5			
Total	0	6	9	104	66	590	290	4	30

* = less than 1 mg. (Continued on next page.)

Table 4. Continued.

Group	Wet weight (milligrams) by Station & Sample								
	42-2	42-3	43-1	43-2	44-3	44-4	45-1	45-2	46-1
Nematoda				*		2	2		
Oligochaeta									
Tubificidae				15					*
Hirudinea									
Glossiphoniidae						8	7		
Conchostraca									
Cyzicidae			24						
Ostracoda									
Cypridae									
Amphipoda									
Gammaridae	*				45	96	7	96	15
Ephemeroptera									
Caenidae							*		
Siphlonuridae									
Baetidae		2							
Odonata									
Agrionidae									
Hemiptera									
Corixidae									
Trichoptera									
Leptoceridae						7			
Molannidae							18	5	
Limnephilidae						199			
Coleoptera									
Dytiscidae					10	5			
Diptera									
Chironomidae	4			*		32	8	2	
Ceratopogonidae							1		
Tabanidae				36				6	
Hydracarina									
Pionidae							1		
Eylaidae									
Pelecypoda									
Sphaeriidae							15	26	
Gastropoda									
Lymnaeidae		199	26			1175			
Planorbidae							7	1	
Physidae									
Valvatidae									
Total	4	201	50	51	55	1524	66	136	15

* = less than 1 mg. (Continued on next page.)

Table 4. Continued.

Group	Wet weight (milligrams) by Station & Sample			
	46-2	47-1	47-2	
Nematoda				
Oligochaeta				
Tubificidae		*		
Hirudinea				
Glossiphoniidae				
Conchostraca				
Cyzicidae				
Ostracoda				
Cypridae				
Amphipoda				
Gammaridae				
Ephemeroptera				
Caenidae	5			
Siphlonuridae				
Baetidae				
Odonata				
Agrionidae				
Hemiptera				
Corixidae				
Trichoptera				
Leptoceridae				
Molannidae				
Limnophilidae				
Coleoptera				
Dytiscidae				
Diptera				
Chironomidae		5	2	
Ceratopogonidae			1	
Tabanidae			14	
Hydracarina				
Pionidae				
Eylaidae				
Pelecypoda				
Sphaeriidae	15	2	11	
Gastropoda				
Lymnaeidae		20	52	
Planorbidae		51		
Physidae				
Valvatidae				
Total	20	79	80	Total for all stations = 16,025 mg

* = less than 1 mg.

Ostracoda

At least three species, all belonging to the Family Cypridae, were found (only in L. Claire).

Amphipoda

Only the genus *Gammarus* was found. Found in both rivers and lakes, it was lacking in the L. Claire samples.

Ephemeroptera

Includes the genera *Caenis*, *Neocloen*, and *Siphlonurus*. They were generally distributed but were not found in L. Claire.

Odonata

Only one specimen of *Ishnura* was found, at Stn. 38 in L. Mamawi.

Hemiptera

Corixids were found primarily in L. Claire.

Trichoptera

These included the genera *Molanna*, *Oecetis*, *Limnophilus*, and *Trienodes*. These seem to be distributed throughout the region.

Coleoptera

A few dytiscid beetles were found at three stations.

Diptera

Chironomids, together with sphacrid clams and small lymnaeid snails, were the most abundant forms and were present at almost every station. A few tabanids and ceratopogonids were also found.

Hydracarina

Three specimens belonging to two families were found. One specimen seems to belong to the genus Forelia.

Mollusca

Fingernail clams belonging to the genera Sphaerium and Pisidium, and snails belonging to the genera Lymnaea, Promenetus, Physa, and Valvata were distributed throughout the area.

All stations which were in areas of open water away from the littoral zone (3, 7, 8, 20, 21, 22, 34, 35, 46) had a very low standing crop (mean: 9 mg wet weight/sample; range: 0-43). Furthermore, the shore stations along the eastern side of Lake Claire (25, 27, 30, 31) also had a very low standing crop (mean: 3 mg wet weight/sample; range: 0-14). This is probably due to the unstable conditions in this area as a result of wave action.

The highest standing crops (greater than 500 mg wet weight/sample) were recorded from the lower reaches of the streams entering the lake system (Birch R., Stn. 23; Mamawi Cr., Stn. 38), from one of the smaller Precambrian Shield lakes (Stn. 44), and from a few channel areas between Lake Claire and Mamawi

Lake (Stn. 1, 2, 6, 24). All the other stations had an intermediate standing crop with a mean value of 100 mg wet weight/sample.

The only other investigations of bottom fauna in this region have been done in Lake Athabasca by Rawson (1947) and McDonald (1965) and did not include the Delta. Rawson's paper is the most comprehensive and will be used for a comparison with the present study.

Rawson stressed the similarity of Lake Athabasca with Great Slave Lake, since both lakes were broadly joined during the retreat of the Keewatin ice sheet. The fish faunas of the two lakes differ little. On p. 74, Rawson states: "In 214 dredgings from all parts of the lake the average population (of benthic invertebrates) was 1,200 per square yard and the average dry weight of organisms 2.9 lbs/acre. This compares closely with the average of 1,275 organisms per square yard and 3.4 pounds dry weight per acre in the main part of Great Slave Lake (excluding the very deep Christie and McLeod bays)."

"The bottom fauna of Lake Athabasca is dominated by the shrimp Pontoporeia, which contributes 61 percent of the numbers and 70 percent of the weight of the population. Similar dominance was observed in Great Slave Lake, where it forms 82 percent of the numbers and 76 percent of the weight" . . . "Minute snails and clams and the larvae of midges make up most of the remainder of the bottom population of Lake Athabasca. They are important as food for bottom-feeding fish especially in the shallow west end

of the lake."

"The resemblance both in quantity and quality between the bottom fauna in Great Slave Lake and Athabasca is helpful in our deductions as to the relative productivity of the two lakes. When we note also the similarity in the amount of plankton and in certain fundamental physical and chemical features, it seems probable that the two lakes have about equal capacity per unit area, for fish production."

Since the 60 samples in this present survey each covered an area of 625 sq cm, the total area sampled was 60 x 625 = 13,500 sq cm or 1.35 sq m. Therefore, the total wet weight collected from the 1.35 sq meters was 16,025 mg or 16.03 gr, the average wet weight per meter would be 11.9 or about 12 gm/sq m.

Rawson's estimate of 2.9 lbs/acre converts to 0.11 gm/sq m of dry weight. Since 70 percent of Rawson's collection consisted of Pontoporeia, whose average dry weight is about 10 percent of its wet weight, the above dry weight value of 0.11 gm/sq m would correspond roughly to 1.1 gm/sq m of wet weight. This is only 10 percent of the present standing crop of 12 gm wet weight per sq m estimated in the present survey. However, this is to be expected since the data from the present survey and that of Rawson's are not directly comparable. Rawson's samples were only taken in Lake Athabasca in the open water zone while those in the 1971 survey included samples from stations in the Delta, Lake Athabasca, and two Shield lakes, primarily in the littoral zone (Fig. 1). It is a well-established fact that the littoral

zone is much more productive, thus distorting any comparison.

This present survey does emphasize the low standing crop of bottom fauna for shallow water regions, especially in Lake Claire. Since this area is particularly important as a nursery for goldeye, the lack of bottom organisms would place a greater dependence upon the zooplankton as a source of food. It has been stated previously that the mature, as well as the young, goldeye generally utilize plankton for food in this area. Due to low standing crops of bottom organisms, this would probably be due to necessity rather than choice, especially for adult fish.

The low standing crop of bottom organisms in many areas of the Delta, especially Lake Claire, may be due to several factors, including low dissolved oxygen, freezing to the bottom under low water conditions, and siltation. However, it is felt that siltation is the most critical factor by making the area unsuitable for most bottom life forms. Constant wind and wave action causes high turbidity with resultant siltation, which is magnified by materials brought in by the various river systems during certain periods of the year. However, a more complete study of bottom invertebrates should be made, since the major portion of Lake Claire, for instance, freezes to the bottom during the winter, according to a water quality study conducted in April, 1971, before ice breakup. Also, nearly all areas of the lake that did not freeze to the substrate contained 0 ppm dissolved oxygen. Both of these factors may contribute to the distribution of certain bottom organisms.

The apparent lack of bottom fauna would have considerable influence upon management of the Delta for both fish and waterfowl and should be considered before final recommendations are made.

CONCLUSIONS AND RECOMMENDATIONS

The following conclusions are based on only one summer's data and must be carefully evaluated before any long-term decisions are made. The preliminary studies reported in this paper should be continued on an annual basis for at least another year. With only one year's data, there is always the danger of making management decisions based on data acquired during an atypical year. For example, abnormally high rainfall in the south during 1971 brought water in via the Athabasca system and presumably caused atypical water levels in the Delta during the study period. Therefore, without further ecological studies, it is not entirely clear what the effects of low water levels, compounded by the W.A.C. Bennett Dam, would have on the Delta ecosystem.

The shallow lakes and waterways of the Delta region are especially important for the production of large crustacean zooplankton organisms. These organisms are necessary as a food source for fish that inhabit this area, especially the fry. Any manipulations that would decrease the abundance of zooplankton or change the species composition would be detrimental to the system. A water control structure which would cause an accumulation of chemicals behind it could be detrimental to certain zooplankton and bottom fauna species, thereby affecting the fish indirectly. Also, a structure that does not allow normal flow patterns in and out of the Delta lakes would not recharge the system with necessary organic detritus for zooplankton food. Evidence indicates that organic material is the main reason for high concentrations of large zooplankton

species. It is therefore recommended that the following studies be initiated or continued:

1. Chemical loading of the Delta lakes should be continuously monitored, especially if permanent dams are constructed.

2. Zooplankton food sources should be further investigated to determine the importance of natural recharging of the system with organic detritus versus phytoplankton primary production.

3. A detailed food study of the fish should be conducted to determine the importance of plankton in the various life stages of the fish and the amounts of each major zooplankton species that are utilized.

4. A seasonal study of the secondary productivity of major zooplankton species should be conducted.

It is concluded that low water, with consequent freezing to the bottom, is nct detrimental to the present zooplankton populations. This was as expected since the major species have resistant stages that can withstand freezing and thawing.

A more detailed study of the bottom invertebrates should be carried out in the Delta region. This study indicates that fish, especially goldeye, are heavily dependent upon zooplankton as a food source due to a lack of bottom organisms and other aquatic insects. However, this can only be proved by further

investigations. Further studies should include (1) the effects that lowered water levels with consequent freezing to the bottom have on the distribution of benthic organisms, (2) the effects that low or zero oxygen concentrations have on certain bottom dwelling organisms in regard to distribution, and (3) the effects of siltation on species distribution and production. This third aspect, siltation, is probably the most important. It is possible that any water impoundment structure which would impede normal inflow and outflow of silt in the Delta, thus allowing much of this material to settle out, would add to the natural siltation process and affect the existing bottom fauna by smothering the organisms or making the habitat otherwise unsuitable. This could be especially serious immediately behind any water control structure.

Since it has been established that the Delta is a nursery for fish, further studies should be conducted on the spawning activities of major species, especially goldeye. If the major spawning activity occurs in the Delta Lakes (i.e., Lake Claire and Mamawi Lake), then consideration has to be given to getting adult fish in and out of the Lakes as well as getting the young fish out at the proper time of the year. It is not known if natural inflow and outflow of water in the Delta are necessary to move fish in or out since they may respond to currents, carefully timed in nature, to move them at the most opportune time for survival. Manipulation of water flow could have disastrous results and should be investigated thoroughly. However, if spawning takes place in the various channels before

entering the lakes, then any water impounding structure would eliminate the fry from these lakes and the food source necessary for survival and/or rapid growth. Therefore, detailed studies should be undertaken before permanent water impounding structures are designed and constructed.

The studies recommended in this report should be initiated as soon as possible since valuable time has been lost. Much information could have been gathered during the past winter regarding bottom invertebrates present in the mud under the ice as well as water chemistry and plankton samples where water existed. This would have provided information necessary for a continuing study.

This study, coupled with other studies of the Delta region, brings out the obvious conclusion that any manipulation of water flow into or within the Delta will affect certain species, both invertebrate and vertebrate, and promote a selection process. Before construction of the Bennett Dam, with natural water flow, there was probably the maximum diversity of species for that particular set of conditions at that latitude. Conditions were probably only near optimum for a particular species for a short period of the year. This, however, allowed for reproduction of the various organisms and maintained maximum species diversity under the existing circumstances. Any manipulations of water levels, including the Bennett Dam, would tend to be a selection process for certain organisms thereby eliminating other species and lowering the diversity. Any process that decreases species diversity in an area can be detrimental to the whole ecosystem.

With a large species diversity, the elimination of one (either naturally or artificially) may have little consequence on the entire system, but when there is limited diversity the destruction of one species may have disastrous effects on this same ecosystem. Therefore, care has to be taken when considering the manipulation of complicated interactions between different organisms and/or between organisms and their environment such as exist in the Peace-Athabasca Delta. All factors should be carefully considered before establishing any definite long-term priorities from a management standpoint.

ACKNOWLEDGEMENTS

This study was made possible by the federal "Opportunities for Youth" program which paid the salaries of the field personnel, the Peace-Athabasca Delta Project which lent support in terms of living accommodations, transportation, and field equipment, and the University of Alberta, Department of Zoology, which lent technical support, sampling equipment and supplies, and laboratory space.

Special acknowledgments must be made to Mr. Gerry Townsend of the Peace-Athabasca Delta Project, Mr. Pat Cruickshank of the Peace-Athabasca field camp in Fort Chipewyan, Mr. Tony Knowles, the Opportunities for Youth supervisor on this project, and Professor John Nuttall of the University of Alberta, for their assistance.

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Appendix Water Temperatures*

Sample Sites	Date	Temp. (°C)
1	June 6 1971	18
2	"	19
3	"	23
4	June 12	18
5	"	20
6	"	22
7	June 13	24
8	"	-
9	"	21
10	June 16	-
11	"	-
12	"	19
13	June 17	19
14	"	20
15	"	19
16	June 18	-
17	"	-
18	"	-
19	"	-
20	June 22	23
21	"	25
22	"	20.5
23	"	19
24	June 24	16
25 (a)	"	21
25 (b)	"	20
26	"	-
27	"	21
28	June 29	-
29	June 30	23
30	July 1	17
31	"	24
32	July 2	22.5
33	"	-
34	July 4	-
35	"	-
36	July 6	-
37	July 16	24
38	July 20	-
39	"	-
40	July 21	16
41	"	17.5
42	"	18
43	"	18.5
44	July 26	-
45	"	-
46	July 27	-
47	"	-

*All temperatures were taken approximately 4 inches beneath the surface. Missing temperatures were due to equipment failure.

SECTION I

VEGETATION MAPPING AND TOPOGRAPHY
OF THE
PEACE-ATHABASCA DELTA

by

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Edmonton, Alberta

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ABSTRACT

Using aerial photography, the vegetation of the Peace-Athabasca Delta was classified into wildlife habitat types. Habitat areas and lengths of shoreline were determined within each of the 11 subdivisions of the Delta, and topographic surveys in the field permitted a determination of the vertical positioning of habitat types. A frequency distribution of spill levels of perched basins was made, and average depths of perched basins were determined. Estimates were made of annual loss of water from perched lakes. These data were collected to provide topographic input to the wildlife simulation model described in Appendix O.

INTRODUCTION

Studies were initiated during spring 1971 to obtain quantitative information on wildlife habitat on the Peace-Athabasca Delta. Because numbers of wildlife on the Delta are partly a function of the amount of habitat available, and because their numbers were determined by sampling within habitat types, the studies required an accurate measure of the present habitat in order to expand sample wildlife population estimates to the entire Delta. A second requirement was for topographic information so that effects of water level fluctuations within the Delta could be expressed in area flooded or exposed at each elevation. Data were needed on vertical positioning of habitat types in order to relate the process of plant succession (Appendix J) to water level changes on the Delta, and so that, using the technique of simulation modelling (Appendix O), quantitative predictions could be made of wildlife numbers possible under various water regimes.

This paper summarizes the information collected about habitat area and shoreline length present in 1970, vertical positioning and depths of perched lakes, vertical ranges of habitat types, and rates of area and shoreline loss within perched lakes between 1968 and 1971.

G. Gentle, D. Surrendi, H. Dirschl, C. Paley, E. Hennan, W. Anderson, and D. Holmes assisted in outlining procedure and/or analyzing the data. Ducks Unlimited (Canada) contributed personnel to the measuring of shoreline on the Delta. Field

studies were carried out by S. White and H. Christensen, students of Opportunities for Youth Corps during the summer 1971. Canadian Engineering Surveys Limited carried out the required survey studies during the winter 1971-72.

METHODS

SUBDIVISIONS OF THE DELTA

The Peace-Athabasca Delta was subdivided into eleven regions on the basis of jurisdiction, proximity to the direct effects of Lake Athabasca and differences in average levels of the major lakes in relation to Lake Athabasca. Subdivisions A, B and C lie in the jurisdiction of Alberta (Figure 1); subdivisions E and F comprise the Chipewyan Indian Reserve; and subdivisions D, G, H, I, j and K lie within Wood Buffalo National Park.

Areas of the Delta that are connected to Lake Athabasca or to one of the major rivers were labelled open-drainage sections. Those areas not connected were classified as restricted-drainage areas. The latter contain numerous perched lakes, marshes or ponds that are characterized by having limited or no outflow and obtain their water either from local runoff or from periodic flooding from the open-drainage systems. The open-drainage systems historically have had fluctuating water regimes, while those of the restricted drainages were characterized by relatively stable water regimes.

VEGETATION MAPPING

Black and white aerial photographs, taken during August and September 1970 at a scale of 1" = 2,000 feet, were used as the basis for preparing a vegetation map. Because of the limitations of photo interpretation and because many plant communities exist on the Delta, it was necessary to limit the total number of

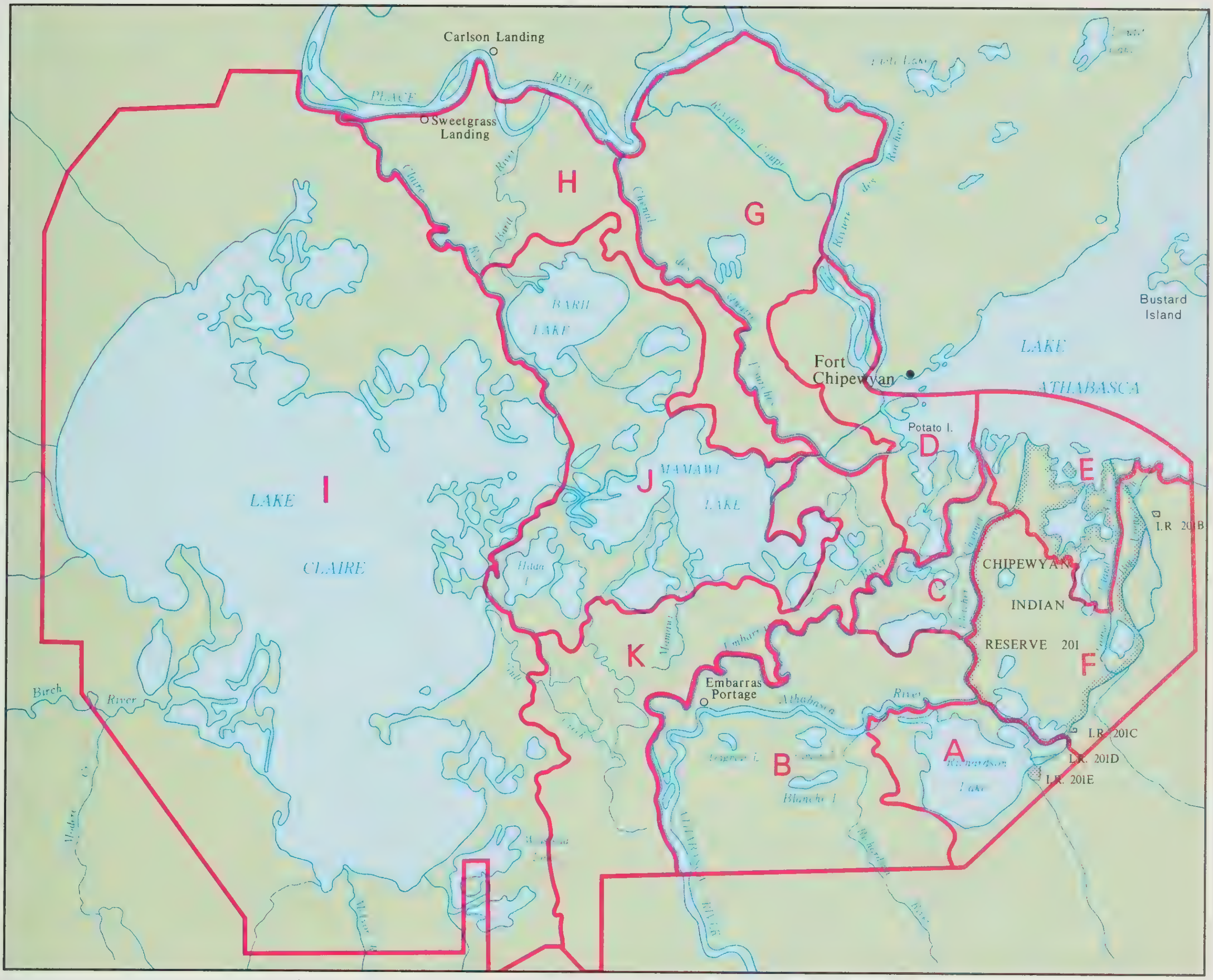


FIG. 1 **Subdivisions of the Peace-Athabasca Delta**

plant types for purposes of this study. Yet these habitat types had to be sufficiently detailed to distinguish animal densities, at least in general terms, for all of the major wildlife fauna. Eleven habitat types were selected as follows, and photographs of representative examples of each are shown in Figures 2 and 3:

1. Water--flooded area devoid of emergent vegetation.
2. Emergents--inundated area that had erect, living vegetation rooted to the substrate.
3. Mud flat--area above water with little or no vegetation growing on it.
4. Immature fen (meadow)--the community resulting from a one-year exposure of mud flats and represented by seedling stages. of *Carex* sp., *Calamagrostis* sp., or shrubs
5. Sedge meadow--area dominated by sedge where woody vegetation is an occasional shrub or tree.
6. Grass meadow--area dominated by *Calamagrostis canadensis* where woody cover is an occasional shrub or tree.
7. Low shrub--woody shrub vegetation under 6 feet tall.
8. Tall shrub--woody shrub vegetation over 6 feet tall.
9. Deciduous--tree communities of primarily deciduous species, mainly balsam poplar and birch.
10. Coniferous--tree communities of conifers.
11. Rock outcrop--the area of the Delta where rock outcrop exists at an elevation above the upper limit of water level consideration.

A group of persons skilled in working with air photographs but not in vegetation interpretation were instructed on photo identification of these habitat types. Color air photographs were used in instruction, although the actual interpretation was done in black and white photography. Both color and black and white ground shots were also used to familiarize the interpreters with the distinguishing habitat characteristics.

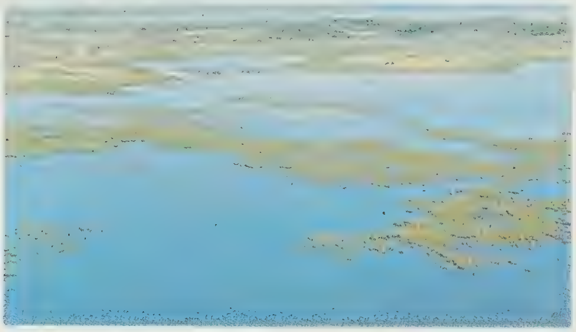
As the first step in mapping, the interpreters drew lines directly onto the photographs by following along the boundaries of each vegetation type, and identified and marked each type with a number. Since it was impossible to distinguish between sedge meadows and grass meadows on black and white air photos, one category representing meadows was used for these two. Once the boundaries were drawn, the air photos were loosely fitted together to form a mosaic, with the overall dimensions being controlled by existing topographical maps. Vegetation boundaries and identification numbers were then traced onto a transparent overlay. While being traced, small adjustments were made to correct for photo-edge distortion by repositioning the individual photographs.

Acreage calculations were made within the boundaries of each habitat type using the dot-grid count system. This was spot checked using a polar planimeter. Each measurement was converted to acres and recorded on the overlay. Boundaries of the subdivisions A through K were drawn on the overlays, and acreage information was summarized from the maps by subdivision and habitat type.

The density of some animals on the Delta is related to length of shoreline rather than to area of a given habitat type. Waterfowl, particularly when they are dispersed on breeding territories, fall into this group. In order to measure production of these animals, it was necessary to determine length of shoreline existing on the Delta. There was the

Fig. 2. Habitat types on the Peace-Athabasca Delta.

Open water



Emergents

Mud flats

Immature fen

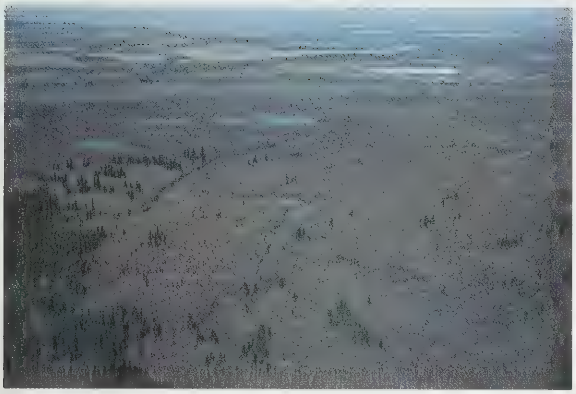
Sedge meadow

Grass meadow

Fig. 3. Habitat types on the Peace-Athabasca Delta.

Low shrub

Tall shrub



Deciduous forest

Coniferous forest

Rock outcrop

Interspersion of several habitat types

possibility that habitat-edge measurements might prove useful for other animal density calculations, and it was decided that measurements would be taken of the interfaces or lines separating each pair of habitat types. This was done and the results were recorded adjacent to the line and converted to miles.

The resolution of the prepared maps was not of sufficient detail to arrive at an accurate measurement of the total shore length on the Delta. The mapped habitat types were fairly broad in area and, in some places within the boundary of the habitat type, there were numerous pockets of open water. The map-measured shorelines therefore were supplemented with additional measurements of shorelines shown on the photographs.

A sample of every sixth photograph that contained small shore edge was selected from the complete coverage of the Delta. Within each mapped habitat unit, the shorelines of open water pockets larger than four acres, and the shorelines of long, narrow water pockets, were measured directly by map measurer. Ponds less than four acres in size were counted and the count was converted to miles of shoreline by multiplying by 0.28. This constant represents the average of the perimeter lengths of ponds one to four acres in size in a variety of shapes ranging from circular to very irregular.

The sample of measured small basins was then expanded to represent the entire subdivision. Shore lengths obtained from the maps were added to the small pond measurements to arrive at

total shoreline existing in 1970.

TOPOGRAPHIC SURVEYS

The topography in the Peace-Athabasca Delta is extremely flat and slight variations in water levels affect large areas of land and vegetation. Contour information is necessary in order to relate plant distribution and succession to depth of water or height above water. The vertical ranges of Delta plant communities are characteristically very narrow and it became evident that the usual techniques of contouring large areas rapidly and inexpensively would not provide the precision required for the study. It was therefore decided to concentrate on obtaining detailed profile information on a representative but small sample of the Delta.

During the winter 1970-71, a total of 191 miles of traverse was run across the west end of Lake Athabasca and across Lake Claire, Mamawi Lake, Baril Lake and Richardson Lake to establish a satisfactory distribution of bench marks over the Delta. Systematically along each traverse, holes were drilled through the ice and bottom elevation was recorded. Four hundred measurements were taken and these data provided information on base elevations of the major open-drainage lakes as well as providing winter 1970-71 ice levels. Results of these surveys are presented in Appendix Volume 1, K.

Additional topographical information was obtained for the perched basins because of their importance to wildlife. A total of 192 survey lines was run on perched basins distributed

throughout the Delta. Each line began in the center of the basin and terminated at the highest point of ground that defined the edge of the basin. In between these two extremes, the elevation of water, if present, was recorded, and spot elevations were recorded at the boundary between mud and vegetation and at the boundaries of each of the habitat types. Distances were short within individual transects and accuracy of ± 0.1 foot was obtained. Accuracy between transects varied depending upon distance, according to the formula:

$$\text{Precision} = \pm\ 0.1 \times \sqrt{\text{distance}}.$$

MEASUREMENT OF WATER LOSS

Aerial photographs from late summer 1968 and 1971 were used to determine changes in areas of water surface and length of shoreline during the three-year period when no floods occurred on a sample of 23 representative perched basins north of Lake Claire and Mamawi Lake. Measurements of shoreline perimeter were made on both sets using a map measurer, and acreage determinations were made using both the dot grid method and the polar planimeter.

RESULTS AND DISCUSSION

VEGETATION MAPPING AND HABITAT MEASUREMENTS

Thirteen overlay vegetation map sheets were prepared to cover the entire Delta. An example, reduced in size, is shown in Figure 4. The thirteen maps were combined, generalized somewhat, and reduced in size to provide a map indicating location of major habitat types on the Delta (Figure 5, pocket inside back cover).

The amount of each habitat type on the Delta in the fall of 1970 is shown in Table 1. Open water and emergents combined indicate that 30 percent of the Delta was covered by water in 1970. The mud flat and immature fen habitats comprise the amount of area which became exposed between 1968 and 1970 during the period of receding water levels following closure of the Bennett Dam. Over 124,000 acres or 8 percent of the Delta were directly affected by a change from aquatic to terrestrial habitat. The meadow habitat accounts for 19 percent, and it is the habitat type which needs periodic flooding to prevent invasion by more persistent shrub species. Thus, 57 percent of the Delta is situated along contours in close proximity to surface water, and the type of vegetation present in 1970 is primarily related to the oscillating water levels of the past and the recent period of declining levels. These declines have caused plant succession to proceed unidirectionally (Appendix J).

Length of shoreline is important to waterfowl production. Within each subdivision, the percentage of open-drainage and

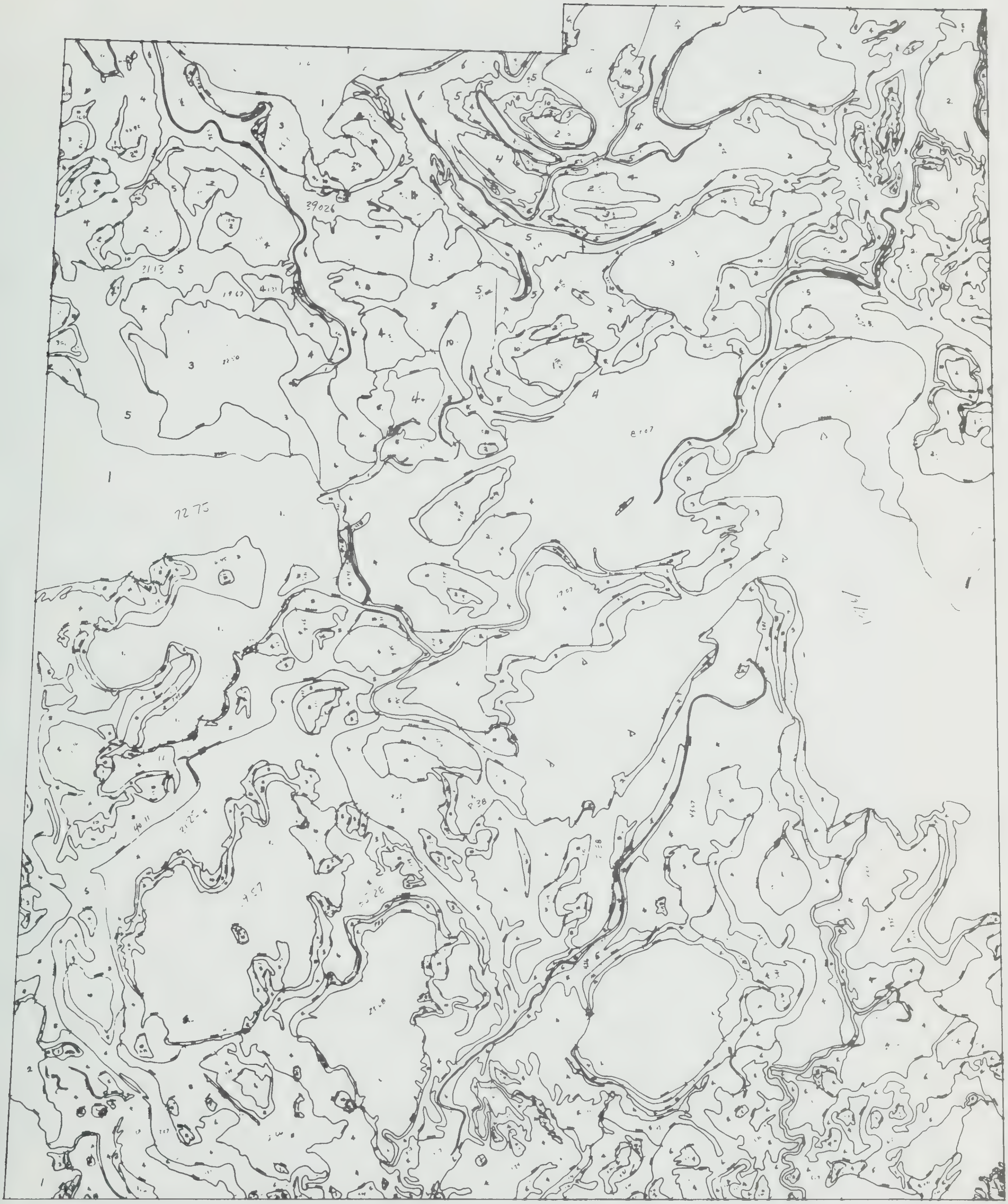


Fig. 4 One of thirteen habitat maps (reduced) prepared from 1970 air photos.

Table 1. Number of acres of each habitat type within each subdivision. Measurements taken from vegetation map prepared from fall 1970 aerial photographs.

Subdivision	Open Water	Emergents	Mud Flats	Immature Fen	Meadow
A	16,686.02	521.65	1,585.02	2,753.48	1,863.48
B	11,270.52	868.38	3,103.00	4,123.45	8,003.57
C	5,669.17	588.52	211.13	2,016.82	1,618.40
D	3,971.54	1,875.49	3,530.00	2,684.66	23,645.14
E	3,744.20	2,400.37	9,938.84	4,378.52	15,386.68
F	8,575.87	2,425,72	580.88	3,878.81	15,601.58
G	10,022.39	2,414.67	1,113.95	1,187.52	15,984.64
H	6,160.95	4,238.86	316.12	1,544.88	7,470.23
I	295,774.76	25,927.98	23,448.35	33,370.32	143,774.67
J	47,206.70	6,544.96	9,783.50	13,123.35	46,035.94
K	7,053.33	1,796.14	232.15	1,415.50	17,154.19
Total	416,135.45	49,602.74	53,842.94	70,477.31	296,538.52

(Continued on next page.)

Table 1. Continued.

Subdivision	Low Shrub	Tall Shrub	Deciduous Forest	Coniferous Forest	Rock Outcrop	Total
A	4,499.92	3,627.31	234.08	——	5,832.72	37,603.68
B	27,489.61	23,450.95	9,951.60	7,715.79	18,696.20	114,673.07
C	7,929.82	2,628.66	169.10	39.17	30.57	20,901.36
D	9,964.74	2,093.51	——	——	1,632.68	49,397.76
E	5,090.35	2,673.21	——	——	192.99	43,805.16
F	40,359.94	10,434.84	1,653.80	6.69	2,016.85	85,534.98
G	26,005.17	17,710.13	4,483.93	11,470.16	24,847.12	115,239.68
H	14,200.01	16,013.97	13,603.57	22,016.22	575.15	86,139.96
I	132,514.39	43,606.99	5,785.97	5,917.72	1,513.35	711,634.50
J	18,213.60	11,008.49	744.25	303.81	121.51	153,086.11
K	28,921.09	32,712.33	8,043.63	14,866.00	2,826.04	115,020.40
Total	315,188.64	165,960.39	44,669.93	62,335.56	58,285.18	1,533,036.66

restricted-drainage habitat was estimated by inspection of air photos and field knowledge of the Delta, and these percentages were applied to shoreline lengths derived from measurement (Table 2). These values do not include measurements of "edge" that do not fall along the shore, such as the emergent - open water interface, which is also important in the production of waterfowl. Table 4.1, Technical Report presents the combined total of shore length and edge.

TOPOGRAPHIC SURVEYS

The wildlife computer model required a determination of the amount of habitat each year that would be flooded at each contour level on the Delta. The presence of perched basins complicates the flooding process considerably, because each basin is connected to the open-drainage system at a different contour level. It was necessary to determine spill levels of a number of perched basins to arrive at an estimate of what proportion of the Delta is flooded at a given elevation of water. A sample of 153 perched basins provided the basis for determining this relationship (Table 3).

Some estimate of depths of perched basins was also necessary in order to determine a measure of permanency of the basin for holding water, and the depth of water present for over wintering muskrats. Table 4 presents information obtained on depths of perched basins.

A third type of information was also obtained from the field surveys. It was necessary to determine vertical positioning of

Table 2. Length of shoreline within each subdivision of the Delta during fall 1970.

Habitat	Subdivision A			Subdivision B		
	Total	Perched	Open	Total	Perched	Open
Mud Flats	54.0	21.1	32.9	94.7	86.2	8.5
Imm. Fen	57.3	22.3	35.0	308.1	280.4	27.7
Meadow	31.5	12.3	19.2	191.3	174.1	17.2
Low Shrub	28.7	11.2	17.5	269.8	245.5	24.3
Tall Shrub	22.6	8.8	13.8	255.5	232.5	23.0
Deciduous	8.6	3.4	5.2	103.9	94.5	9.4
Coniferous	10.5	4.1	6.4	79.9	72.7	7.2
Rock	0.3	0.1	0.2	1.9	1.7	0.2
Total	213.5	83.3	130.2	1,305.1	1,187.6	117.5

Habitat	Subdivision C			Subdivision D		
	Total	Perched	Open	Total	Perched	Open
Mud Flats	7.8	1.3	6.5	19.3	4.2	15.1
Imm. Fen	117.4	20.0	97.4	72.1	15.9	56.2
Meadow	21.2	3.6	17.6	162.9	35.8	127.1
Low Shrub	107.7	18.3	89.4	230.9	50.8	180.1
Tall Shrub	42.7	7.3	35.4	54.0	11.9	42.1
Deciduous	0.9	0.2	0.7	0.0	0.0	0.0
Coniferous	0.0	0.0	0.0	0.0	0.0	0.0
Rock	0.0	0.0	0.0	2.2	0.5	1.7
Total	297.7	50.7	247.0	541.4	119.1	422.3

Habitat	Subdivision E			Subdivision F		
	Total	Perched	Open	Total	Perched	Open
Mud Flats	147.5	28.0	119.5	16.2	13.9	2.3
Imm. Fen	82.2	15.6	66.6	172.4	148.3	24.1
Meadow	121.6	23.1	98.5	219.4	188.7	30.7
Low Shrub	84.1	16.0	68.1	327.4	281.6	45.8
Tall Shrub	9.0	1.7	7.3	69.0	59.3	9.7
Deciduous	0.0	0.0	0.0	55.0	47.3	7.7
Coniferous	0.0	0.0	0.0	0.0	0.0	0.0
Rock	0.0	0.0	0.0	0.0	0.0	0.0
Total	444.4	84.4	360.0	859.4	739.1	120.3

(Continued on next page.)

Table 2. Continued.

Habitat	Subdivision G			Subdivision H		
	Total	Perched	Open	Total	Perched	Open
Mud Flats	35.2	31.3	3.9	16.3	12.2	4.1
Imm. Fen	13.8	12.3	1.5	37.2	27.9	9.3
Meadow	378.7	337.0	41.7	167.9	125.9	42.0
Low Shrub	303.4	270.0	33.4	181.4	136.0	45.4
Tall Shrub	150.8	134.2	16.6	166.9	125.2	41.7
Deciduous	41.7	37.1	4.6	74.7	56.0	18.7
Coniferous	86.1	76.6	9.5	156.3	117.2	39.1
Rock	128.4	114.3	14.1	5.6	4.2	1.4
Total	1,138.1	1,012.8	125.3	806.3	604.6	201.7

Habitat	Subdivision I-J			Subdivision K		
	Total	Perched	Open	Total	Perched	Open
Mud Flats	621.6	634.6	87.0	5.3	4.0	1.3
Imm. Fen	890.8	766.1	124.7	53.3	40.0	13.3
Meadow	1,760.9	1,514.4	246.5	192.3	144.2	48.1
Low Shrub	890.7	766.0	124.7	256.7	192.5	64.2
Tall Shrub	347.5	298.8	48.7	330.5	247.9	82.6
Deciduous	44.8	38.5	6.3	92.9	69.7	23.2
Coniferous	13.2	11.4	1.8	104.4	78.3	26.1
Rock	3.6	3.1	0.5	10.6	7.9	2.7
Total	4,573.1	3,932.9	640.2	1,046.0	784.5	261.5

Habitat	Chipewyan Reserve			Alberta Portion		
	Total	Perched	Open	Total	Perched	Open
Mud Flats	163.7	41.9	121.8	156.5	108.6	47.9
Imm. Fen	254.6	163.9	90.7	482.8	322.7	160.1
Meadow	341.0	211.8	129.2	244.0	190.0	54.0
Low Shrub	411.5	297.6	113.9	406.2	275.0	131.2
Tall Shrub	78.0	61.0	17.0	320.8	248.6	72.2
Deciduous	55.0	47.3	7.7	113.4	98.1	15.3
Coniferous	0.0	0.0	0.0	90.4	76.8	13.6
Rock	0.0	0.0	0.0	2.2	1.8	0.4
Total	1,303.8	823.5	480.3	1,816.3	1,321.6	494.7

(Continued on next page.)

Table 2. Continued.

Habitat	Wood Buffalo Park			Entire Delta		
	Total	Perched	Open	Total	Perched	Open
Mud Flats	697.7	586.3	111.4	1,017.9	736.8	281.1
Imm. Fen	1,067.2	862.2	205.0	1,804.6	1,348.8	455.8
Meadow	2,662.7	2,157.3	505.4	3,247.7	2,559.1	688.6
Low Shrub	1,863.1	1,415.3	447.8	2,680.8	1,987.9	692.9
Tall Shrub	1,049.7	818.0	231.7	1,448.5	1,127.6	320.9
Deciduous	254.1	201.3	52.8	422.5	346.7	75.8
Coniferous	360.0	283.5	76.5	450.4	360.3	90.1
Rock	150.4	130.0	20.4	152.6	131.8	20.8
Total	8,104.9	6,453.9	1,651.0	11,225.0	8,599.0	2,626.0

Table 3. Perched basins grouped according to elevations of upper basin edges (spill levels). Includes basins surveyed in subdivisions C,D,E,F,G,H,I, and J. Excludes basins having upper edges higher than 693 feet, because these are beyond the influence of Lake Athabasca levels. Sample size is 153.

Elevation (Feet)	Percentage	Cumulative Percentage
685.6 - 686.0	1.3	1.3
686.1 - 686.5	3.3	4.6
686.6 - 687.0	2.6	7.2
687.1 - 687.5	6.5	13.7
686.6 - 688.0	9.2	22.9
688.1 - 688.5	12.4	35.3
688.6 - 689.0	18.3	53.6
689.1 - 689.5	11.1	64.7
689.6 - 690.0	13.1	77.8
690.1 - 690.5	4.6	82.4
690.6 - 691.0	6.5	88.9
691.1 - 691.5	2.6	91.5
691.6 - 692.0	3.3	94.8
692.1 - 692.5	2.6	97.4
692.6 - 693.0	2.6	100.0

Table 4. Mean depths of perched basins, grouped according to elevations of spill level.

Elevation	Mean Basin Depth (Feet)	Range	Sample Size
685.6-686.0	2.6	2.2-2.9	2
686.1-686.5	1.4	0.4-2.2	4
686.6-687.0	1.6	0.4-2.5	4
687.1-687.5	1.5	0.8-2.2	7
687.6-688.0	1.8	0.8-4.3	12
688.1-688.5	2.2	1.3-2.8	13
688.6-689.0	2.9	0.6-5.8	25
689.1-689.5	3.6	0.9-8.2	14
689.6-690.0	3.6	1.6-4.4	11
690.1-690.5	3.1	1.9-4.8	6
690.6-691.0	3.7	2.1-4.9	7
691.1-691.5	2.8	0.4-4.6	3
691.6-692.0	4.4	3.0-6.0	3
692.1-692.5	4.8	4.2-5.3	2
692.6-693.0	6.5	6.2-6.7	2
693.6-694.0	7.2	7.0-7.4	2
694.1-694.5	9.8		1
695.1-695.5	9.0		1
695.6-696.0	5.9		1
698.6-699.0	9.4		1
700.6-701.0	39.8		1

the major habitat types on the Delta in relation to vertical distance from water, so that one could forecast what habitat types would be flooded with a given rise in lake levels. The vertical ranges of the major habitat types are given in Table 5, in what is considered approximate ascending order on the Delta. It is recognized that not all of these habitat types are necessarily represented in each perched basin, but over the years, water level fluctuations and plant succession have more or less stratified the habitat types according to this ascending order.

MEASUREMENT OF WATER LOSS

A knowledge of rate of water loss from perched basins was necessary in order to program loss of perched basin shoreline and flooded acres under simulated no-flooding conditions in the wildlife computer model. The measurements taken from the two sets of aerial photographs of different years provided the estimate (Table 6). Between 1968 and 1971 levels of Lake Athabasca or any of the rivers were not high enough to flood any of the measured basins, and the changes determined reflect water loss or gain due to various combinations of local precipitation, local runoff, evaporation, transpiration, and sublimation during the interval. The assumption made is that the average rate of loss of water on this group of basins is more or less representative of the majority of basins on the Delta. It is believed that these figures are reliable for shallow basins with gently sloping edges, but that the rate of water loss on basins with steeper sides was not as great. Loss of shoreline length

Table 5. Average vertical ranges of habitat types on the Peace-Athabasca Delta, 1971.

Habitat Type	Mean Height (feet)	Sample Size
Mud Flat	0.9 ± 0.2	68
Immature Fen	1.4 ± 0.2	93
<u>Carex</u>	1.3 ± 0.2	124
<u>Calamagrostis</u>	2.3 ± 0.6	24
Low Shrub	1.8	1
Tall Shrub	1.7 ± 0.3	101
Deciduous Forest	3.0 ± 1.4	17
Coniferous Forest	5.0	2

Table 6. Area of surface water loss and shoreline loss from perched basins between 1968 and 1971, as determined by measurements of aerial photographs.

Perched Basin Ident.	Shoreline (Feet) 1968 Measure	Shoreline (Feet) Change By 1971	Area (Acres) 1968 Measure	Area (Acres) Change By 1971
A	17,800	-3,200	639.6	-316.8
B	11,616	-11,616	192.0	-192.0
C	21,200	-3,400	1,188.0	-194.4
D	14,520	-14,520	134.4	-134.4
E	6,600	-6,600	54.4	-54.4
F	29,600	-1,400	1,016.4	-98.4
G	10,032	-4,224	156.8	-108.8
H	6,800	-1,600	168.0	-55.2
I	10,600	-200	108.0	-6.0
J	4,600	+400	73.2	-8.0
K	11,800	-200	151.2	-8.4
L	7,800	-800	109.2	-0.4
M	7,000	0	57.6	-5.4
N	11,200	-2,800	104.4	-37.2
O	10,400	-8,600	44.4	-34.8
P	10,000	-3,600	88.8	-25.2
Q	17,688	-16,896	204.8	-182.4
R	22,176	-5,976	380.8	-230.8
S	12,600	-3,200	114.0	-15.6
T	11,200	-1,400	81.6	-10.8
U	13,200	+2,000	403.2	-110.4
V	14,500	-14,500	368.0	-368.0
W	10,200	-1,600	276.0	-121.2
Total	293,132	-103,932	6,114.8	-2,319.0
%Change		36		38

was 36 percent of 55.5 miles present in 1968 and loss of water surface area was 38 percent of 6,100 acres measured. Thus, there was an average loss of both shoreline and water surface of approximately 12 percent per year.

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SECTION J

TRENDS IN VEGETATION SUCCESSION
IN THE PEACE-ATHABASCA DELTA

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INTRODUCTION

Concern about the potential ecological effects of the altered water regime of the Peace-Athabasca Delta, following completion of the W. A. C. Bennett Dam on the Peace River, led the Canadian Wildlife Service in 1968 to initiate an ecological study of the Delta. Its objectives included:

(1) To determine the relationships between vegetational patterns and physical environmental features, particularly the water regime, and to develop a landform/vegetation classification of the Delta's landscape;

(2) To determine the prevailing, long-term successional trends in the Delta; and

(3) To monitor and assess the ecological adjustments initiated by the altered water regime.

A subsidiary objective of the study was to determine use of various habitat types by waterfowl populations for breeding, nesting, brood rearing, molting, and spring and fall staging.

Research on the landscape-ecological aspects of the study was carried out between May and September of 1968 to 1971. The waterfowl aspect was restricted to the seasons of 1969 and 1970 and then continued by Ducks Unlimited (see Appendix K).

Preliminary results of the landscape-ecological aspects of the study are reported in the following publications and progress reports: Dirschl (1970a, 1970b, 1971, 1972), Dirschl and Dabbs

(1972), and Dabbs (1971). A comprehensive report on the study is in preparation. Results of the waterfowl aspect are contained in Nieman (1971) and Nieman and Dirschl (in press).

Following the organization of the Peace-Athabasca Delta Project by joint action of the governments of Canada, Alberta, and Saskatchewan, the study provided important background data for the formulation of the wider objectives of that federal-provincial undertaking. It also furnished input for the wildlife productivity simulation model (see Appendix O).

This report discusses the concept of ecological succession as it applies to deltas generally and to the Peace-Athabasca Delta in particular. It attempts to elucidate the successional patterns - both the prevailing long-term events and the ecological changes initiated by recent low water levels. Finally, it provides crude estimates of the rate at which the major successional sequences are thought to proceed under the influence of different water level regimes.

THE CONCEPT OF SUCCESSION APPLIED TO DELTAS

River deltas are landscape systems in a state of perpetual dynamic change. A delta originates when a river begins to empty into a lake or the sea; it grows downstream as the river approaches base level and deposits its sediment load. Point bars and islands begin to emerge within the stream bed, and the river branches into a series of channels that meander across the forming delta plain. As the river continues to adjust to the base level, channels deepen through bottom erosion in the upper

reaches of the delta while, through silt deposition at the lower end, the delta continues to advance into the lake or the sea. Local differences in erosion and deposition result in the cutting-off and ponding of channels (oxbows) and in the formation of numerous shallow depressions on the delta plain (perched basins). In this manner, a delta continually grows downstream as it matures at the upstream end.

Parallel with the evolution of the physical landscape occurs a development of the biological ecosystem components. Plant species, capable of becoming established in the aquatic and nutrient-rich environment of young sites, will be replaced by species adapted to drier and nutrient-poor conditions. Thus, the vegetation occupying a given location changes in time from aquatic, to meadow, to wooded communities. Animal populations exhibit a similar change as their habitat is altered by these delta-forming processes.

The phenomenon of continuing replacement of plant and animal communities, over time, is referred to as _ecological succession_, and the sequence of communities is termed a _sere_.

The main driving force of ecological succession in a delta, therefore, is the evolution of the physical landscape pattern ("allogenic" succession). However, the plant communities play a modifying role in this process, e.g., by locally reducing flow rates and entrapping silt or by accumulating organic matter in perched basins, backswamps, and over the emerging delta plains. Moisture, nutrient, and soil temperature conditions are thereby

changed by the vegetation itself and rendered suitable for the invasion by species adapted to the modified environment ("autogenic" succession).

Plant succession normally proceeds too slowly to permit direct observation of the sequence through which communities change in a given location. Since a delta, however, develops in such a way that the youngest sites occur at the downstream extremity whereas progressively older sites are found towards the upstream end, the broad geographic zonations of landform and vegetation types present a spatial display of the long-term successional sequence.

Superimposed on this overall successional deltaic development, which proceeds over a time-span measured in decades and even centuries, are natural events that proceed at a much faster pace. These are caused by such environmental influences as periodic droughts and floods, lightning fires, etc. Such physical forces produce abrupt changes in the local environments affected, which, in turn, initiate rapid adjustments in vegetation pattern and existing wildlife habitats. These rapid changes in plant cover and the consequent changes, positive or negative, in the abundance of some wildlife species are readily observable and are intimately familiar to those who derive their livelihood from the delta or find aesthetic enjoyment within deltaic landscapes. Our interest, therefore, quite naturally tends to focus on the short-term interactions between the physical environment and the biological ecosystem components rather than on the long-term successional trends. However, as

the processes occur simultaneously, it is clearly impossible to study one without reference to the other.

So far, the discussion has been confined to natural deltaic processes: long-term successional trends and short-term cyclic fluctuations of the physical environment which cause rapid adjustments within the ecosystem. It should be stated, at this point, that man-made environmental alterations likewise produce ecological changes within a delta. Reduction in river flow through upstream diversion or impoundment results in the expansion of terrestrial communities and concurrent reduction in aquatic and marsh habitats and thus increases the rate of aging of the delta.

Conversely, raised water levels within the delta, resulting from increased river flow or from downstream impoundment, enlarge the area occupied by aquatic and marsh habitats at the expense of terrestrial communities; thus succession is set back to an earlier seral stage.

Man-induced ecological changes of this type are not fundamentally different from those that occur naturally. It is beyond the scope of the scientist to place a value judgment upon these phenomena. Beneficial or detrimental consequences are perceived through the social values that society places upon the ecosystem in question and its component resources. Ecological scientists can identify effects and present alternative courses of action, but judgments as to the desirability of alternatives must be made on the basis of the goals and aspirations of society.

DELTAIC PROCESSES IN THE PEACE-ATHABASCA DELTA

The Peace-Athabasca Delta is a complex of the deltas of three rivers, the Peace, the Athabasca, and the Birch, which, since deglaciation, ca. 10,000 years ago, have emptied into the lowlands at the western extremity of Lake Athabasca (Bayrock and Root, 1971). The ecological character of the Peace-Athabasca Delta has evolved through a unique hydrological system formed by the interaction cf these rivers and Lake Athabasca and its outflow channels. Under natural conditions, the lower Peace River experienced a spring flood of variable height during which time it acted as a hydrological dam which stopped and, to some extent, reversed the outflow from Lake Athabasca and the contiguous Delta lakes. Consequently, the rising level of Lake Athabasca flooded most of the Delta and recharged lakes and the numerous perched basins with nutrient-rich waters, deposited silt and plant seeds, and flushed out or buried plant debris. During the remainder of the year, outflow and evapotranspiration gradually lowered the water levels within the Delta. This flood, occurring in most years, had the effect of slowing the normal long-term deltaic development and holding much of the area at early successional stages (Fuller and LaRoi, 1971). It is important to realize that the vegetation patterns and animal life, which now characterize the Delta, have developed in response to this fluctuating water level regime and are thus adapted to it. Any change in the hydrological regime, therefore, initiates ecological adjustments within the system (Dirschl, 1972).

During the filling of Lake Williston (the reservoir behind W. A. C. Bennett Dam) which began in December, 1967, and has taken four years, the annual high stage on the Peace River has been much reduced. Hydrological studies have shown that once the reservoir is filled, the water regime will not be fully restored unless remedial action is taken.

METHODS AND TECHNIQUES

The methods and techniques used in this study have been previously described by Dabbs (1971) and Dirschl (1972). Therefore, only a brief resume is included here.

Information on the existing vegetation pattern was obtained by mapping sections of the Delta from existing small-scale aerial photographs and uncorrected photo mosaics. The developed classification was later extended to the entire Delta by the Peace-Athabasca Delta Project and provided input to the wildlife production simulation model (Appendix O). To obtain detail on the relationships between vegetation, landform, and water regimes, representative transects (Fig. 1) were marked with targets on the ground, photographed from the air with black-and-white, true color, and color infrared film, and mapped by means of air photo interpretation and ground checks. This resulted in the development of a detailed landscape classification (Dabbs, 1971; Dirschl et al., 1972, in prep.). Topographic relationships were further examined by means of level-surveying part of the photographed field transects (Fig. 2).

Since 1968, the vegetational adjustments initiated by the lowering water levels have been monitored by annual sampling of marked stands on emerging silt bottoms of Lake Athabasca and Mamawi Lake, as well as by repetitive large-scale (1:6,000) aerial photography and interpretation of representative transects.

Long-term successional trends were studied by comparing existing

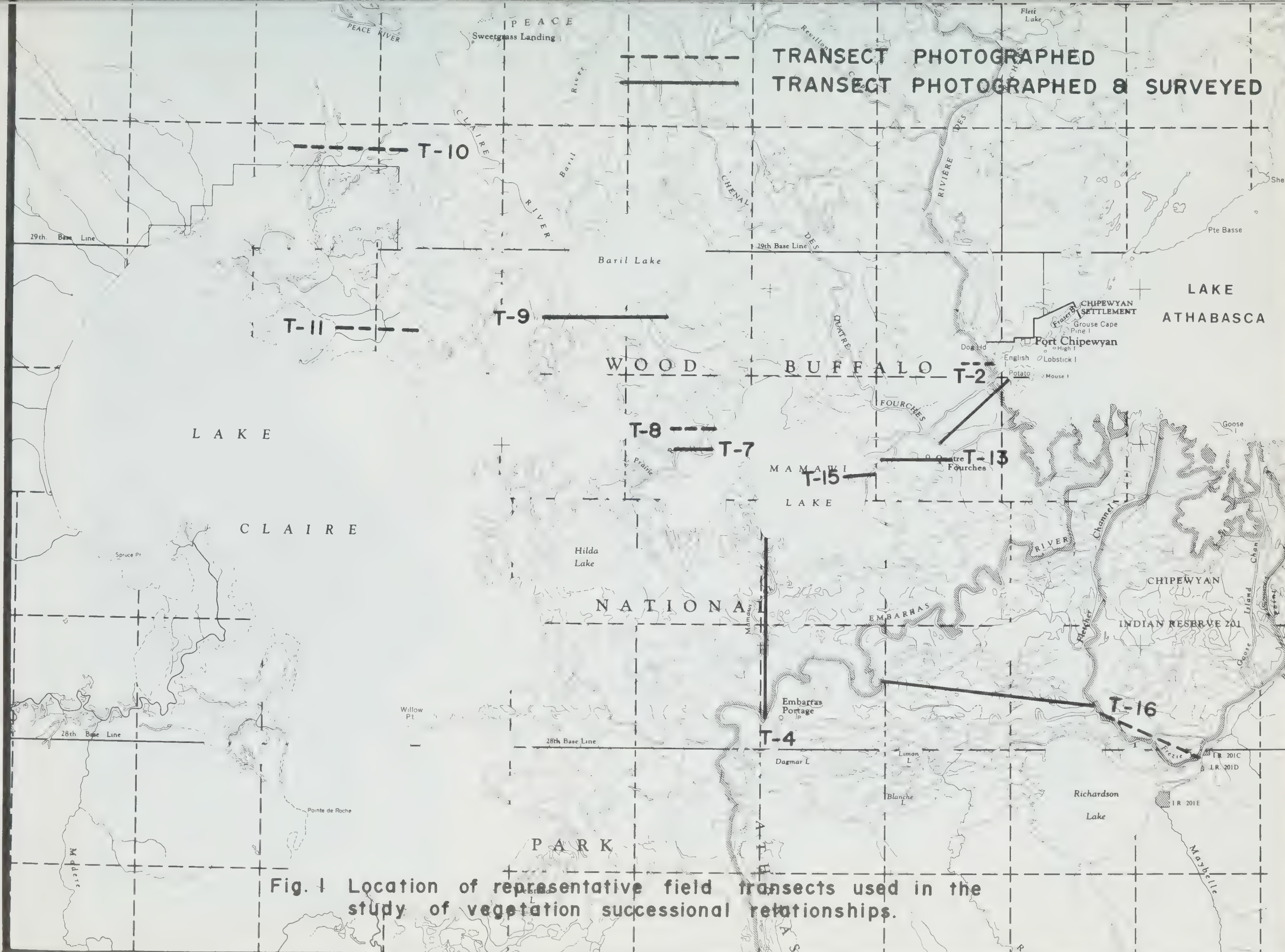
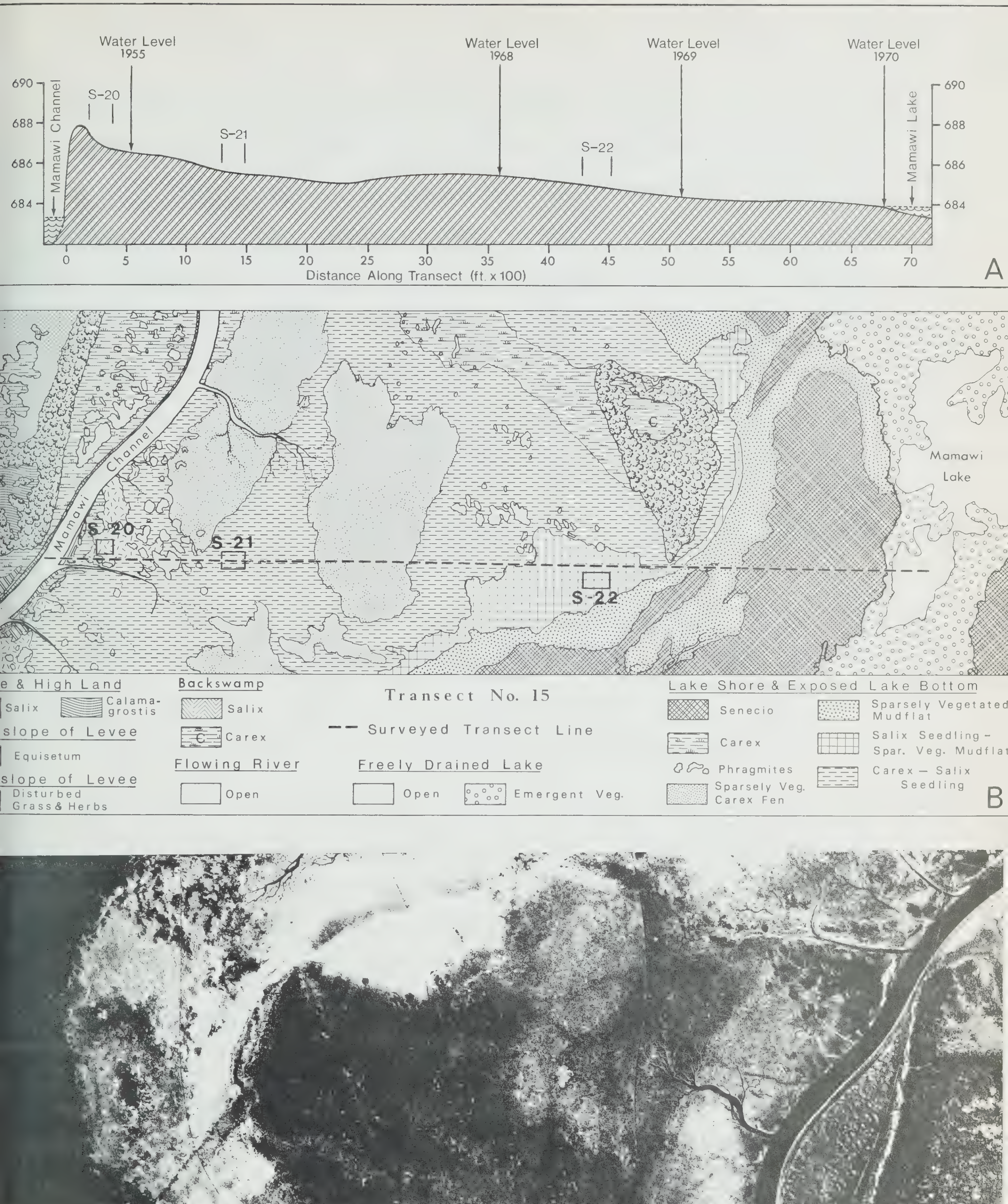


Fig. 1 Location of representative field transects used in the study of vegetation successional relationships.



ig. 2 Example of the representative field transects used in the study (Transect 15) including strip-mosaic prepared from 70 mm. air photos, detailed land facet-vegetation map and topographic profile.

sets of small-scale vertical air photos taken periodically since 1945 and by comparison with sections of the Delta mapped by Raup (1935). Multivariate classification (agglomerative association analysis) of 89 stand-samples, covering the full vegetation spectrum, was used to relate vegetation types to landscape features (including soil and groundwater analyses) and to determine successional patterns.

VEGETATION ZONATION AND LANDFORM

The distribution of the major components of the Delta's present vegetation pattern and their position in respect to topography and water levels have been described in the preceding report (Appendix I). It now remains to briefly discuss the existing plant cover in relation to the dynamic deltaic processes (landform develcpment, allogenic and autogenic succession) that have brought about and continue to mold this pattern.

The modern landscape of the Peace-Athabasca Delta is a function of the historic development of river and stream channels. Changing flow patterns are recorded by meander scrolls which control the shape of shorelines and the existence of backswamps. All lakes and the numerous perched basins within the Delta have been formed by the levee-building process through which large areas have been cut off and isolated from the normal drainage channels. The present distribution of the major physiognomic vegetation types (e. g., meadows, shrub carrs, forest) primarily relates to levees - either of active streams or old, inactive streams - which provide higher ground and gradually sloping land

surfaces where the vegetation has arranged itself according to the ecological requirements and competitive interactions of the constituent species (Dabbs, 1971).

The annual spring flood has been instrumental in this process by providing the silt load for levee development and by gradual filling-in of perched basins and backswamps. This supply of nutrient-rich water to recharge lakes and perched basins has counteracted the evaporation process and has maintained minerotrophic conditions over the large portion of the Delta that was affected by the flood.

Therefore, it is obvious that permanent loss of the spring flood would cause ecological adjustments throughout the active and semiactive portions of the Delta, resulting in a shift of the vegetation zonations toward more mesophytic (drier) conditions. Thus shallow perched basins would completely dry out and become covered over with meadows and willow shrub, while existing meadows would develop into shrub carrs and, eventually, forested communities. Conversely, any means that would tend to re-establish the previous fluctuating water level regime (downstream dams and weirs, etc.) would initiate a gradual return to the previous vegetation pattern. The degree to which this can be achieved depends on (1) how long the present drying trend is allowed to proceed, and (2) to what degree the natural, fluctuating water level regime (seasonal and long-term) can be reproduced by man-made regulation.

VEGETATIVE ADJUSTMENTS TO RECENT LOW WATER LEVELS

Since 1968, the level of Lake Athabasca has remained several feet below the previous long-term average (Bennett, 1971). Water levels of the Delta lakes, which are connected with Lake Athabasca through a network of channels, have experienced a similar decline. Owing to the level topography of the Delta, the falling water levels have led to gross reductions in open water areas. By the summer of 1970, the total area of the nine largest water bodies had decreased by 28 percent (Dirschl, 1972). The numerous perched basins, dotting the Delta plain, have, in the absence of the annual spring flood, progressively dried up through evaporation and transpiration at the approximate rate of 12 percent per year (Appendix I).

The extensive silt flats, emerging from the shrinking lakes and ponds, have experienced extremely rapid colonization by germinating seeds that had been present within the silt or were distributed by wind. This colonization proceeded from an open mud flat, with scattered seedlings of emergent aquatics, sedges, and grasses during 1968, to an immature fen, consisting of a complex assembly of herbaceous plants, in 1969 and 1970. By summer, 1971, dense sedge meadows dominated by _Carex atherodes_ had developed. On the silt flats surrounding Mamawi Lake, numerous willow seedlings began to germinate in 1969; by 1971 they had reached a height of five to six feet and had become visually dominant (Figs. 3-6). In other parts of the Delta, particularly in perched basins, willow seedlings were less abundant, but the development of herbaceous cover proceeded at a

similar rate.

Study plots and repeated aerial photography have also shown that sedge (Carex) meadows that existed prior to 1968 are beginning to change in species composition toward drier Calamagrostis canadensis meadows. Previously existing, small Phragmites communis clumps have also begun to spread over wider adjacent areas of previous lake shore.

Water levels as low as those experienced during the 1968-71 period have occurred naturally from time to time, e.g., during 1944-46 (Fuller, 1951; Bennett, 1971). Consequently, the observed plant colonization of lake bottoms must also have occurred but subsequently been reversed during floods. A number of the soil pits dug in this study have revealed thin layers of fen vegetation and charcoal seams buried beneath silt deposited by floods (Dirschl, 1972).

It is quite clear that the described colonization of newly emerged silt sites, which has occurred in response to the falling lake levels or the drying up of perched basins, represents a stage in the long-term successional trends operating in the Delta. These long-term events will be discussed in the following section.

LONG-TERM SUCCESSIONAL TRENDS

Paup (1935, p. 88) produced an outline of plant succession in the Athabasca, Peace, and Slave River lowlands, based on his field research in the years 1926-30. Our studies have led us to

Fig. 3

Fig. 4

Fig. 5

Fig. 6

modify Raup's successional sequences in order to make them a specific and accurate portrayal of the long-term successional processes that we consider to operate in the Peace-Athabasca Delta (Fig. 7).

Within the total Delta complex, three broad categories are distinguished according to the prevailing physical deltaic processes (Fig. 7):

(1) Active delta,

(2) Semiactive delta, and

(3) Inactive delta.

The _active delta_ (Fig. 8) consists of flowing rivers and their deposits (point-bars), levees, and a very gently sloping delta plain surrounding the open basin lakes (i.e., those locations directly affected by the hydrological interactions of the major rivers and Lake Athabasca). _Semiactive delta_ (Fig. 9) includes perched basins and cut-off stream channels, i.e., locations which are not connected with the major hydrological system but have been recharged by the spring flood in most years. The _inactive delta_ (Fig. 10) comprises closed basins (old meander scrolls and backswamps) which are positioned on the higher, older portions of the Delta, and are affected by the spring flood only during extreme high-water years. Therefore, in broad terms, nutrient availability decreases from left to right.

The various plant communities recognized in the replacement series have been grouped into five community-types (corresponding terms used in the simulation model, Appendix I and O, are listed in parentheses) as follows:

(1) Aquatic communities (open water);

(2) Shore communities (emergents, mudflat, immature fen);

(3) Meadow communities (Carex meadow, Calamagrostis meadow);

(4) Shrub communities (low shrub, tall shrub); and

(5) Forest communities (deciduous forest, coniferous forest).

In this sequence, within active and semiactive delta locations, aquatic and emergent communities are replaced by various shoreline pioneers on emerging mud flats, which develop into fen meadows. These meadows then change into willow shrub communities and eventually develop into terminal forest communities. It is obvious from the chart that succession in the Delta does not follow a single pathway, but takes the form of a branching network in which various species or species-groups may dominate, in different locations during the same seral stage, and fuse during a succeeding stage. The variety of alternate dominance-types is particularly great among shoreline and meadow communities.

It is not always clear why sites, which appear to be identical, are occupied by different species groups. The following factors, however, are involved in producing this diversity:

(1) The supply of plant seeds at the time when conditions are favorable for germination; and

(2) Minute local differences in moisture and nutrient status.

While the vegetative replacement series in active and semiactive delta environments is mainly driven by allogenic forces, succession in the inactive delta locations is controlled

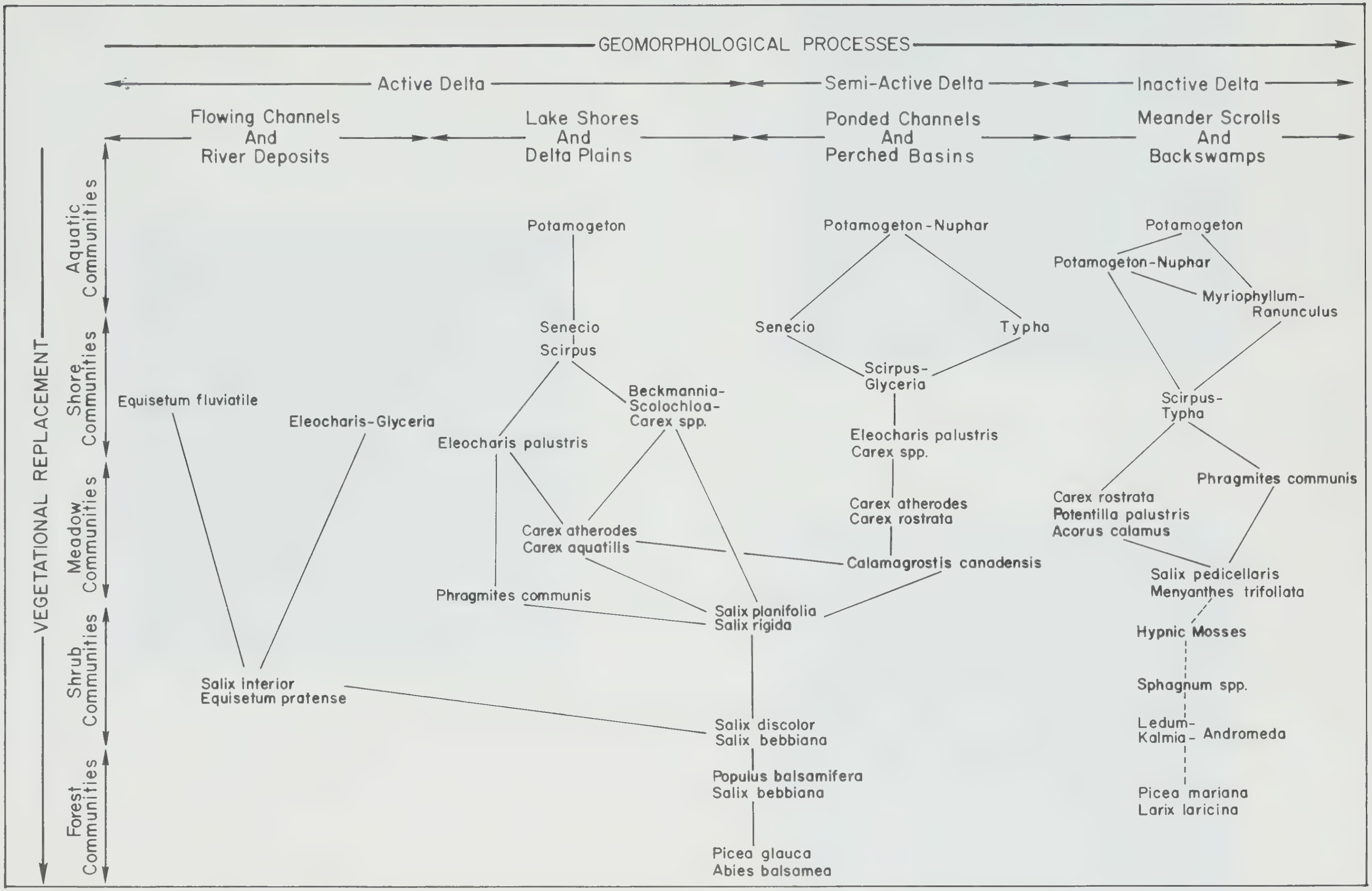
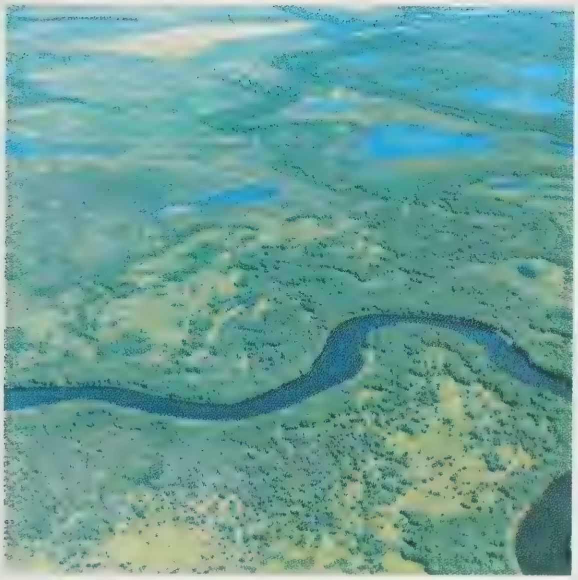


Fig. 7 Outline of vegetation successional trends in the Peace - Athabasca Delta.



[redacted] Fig. 9

[redacted] Fig. 8

Fig. 10

predominantly by autogenic processes. Here the lack of a source of nutrient-rich waters results in a gradual fixing of the available nutrients in undecomposed vegetative matter, in the growth of floating sedge mats over the basin, and finally in the filling of the entire basin with muck and peat.

In this process, the peat surface eventually grows completely out of reach of the mineral water table, is invaded by Sphagnum mosses, and develops into an ombrotrophic bog or muskeg. Because of the frequency of previous high floods, inactive delta is largely confined to the upper portion of the Athabasca Delta and, even there, has not evolved beyond the floating mat stage. Permanent elimination of the spring flood, however, would speed the development toward ombrotrophic bog in backswamp locations. For example, in the Saskatchewan River Delta, where major floods have historically been much less frequent, extensive bogs are found (Dirschl and Coupland, 1972).

The time frame within which long-term succession proceeds is not well understood. We know that the entire vegetational development took place during the past 10,000 years. It is difficult, however, to determine the average rate by which seral stages replace each other. The narratives of the early explorers and fur traders, who passed through the Peace-Athabasca Delta, suggest that the Delta's overall appearance has not changed in 300 years (see Fuller and LaRoi, 1971).

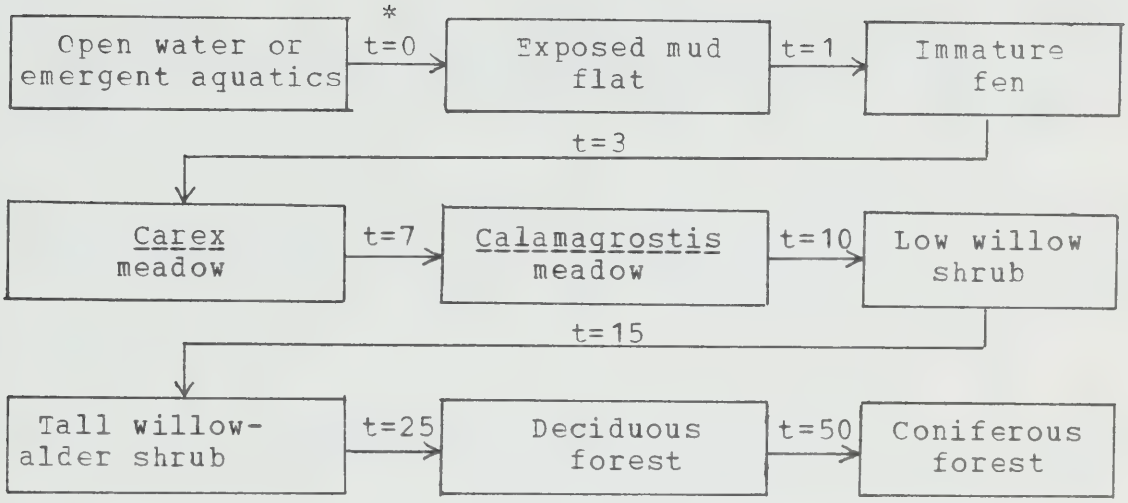
Locally, however, some successional changes can be verified. For example, H. M. Raup mapped an area south of Mamawi Lake in 1930

(Raup, 1935). This area (Transect 4) was remapped during the present study from air photos taken in 1970 (Dabbs, 1971). A comparison of the two maps shows that the younger low-lying positions close to the Lake have all changed to a greater or lesser extent. Most of these locations in 1930 consisted of meadows dominated by Carex atherodes. Forty years later, in many of these low-lying areas, Calamagrostis meadows had replaced the Carex stage, and in some areas low willow shrub had become established.

From our study of the colonization of mud flats that followed the closure of the Bennett Dam, we know that early successional changes from bare silt surface, to immature fen, to meadows and low willow shrub, can occur within a few years under conditions of continually low water levels.

From the limited data on hand, it is apparent (1) that successional events in the Delta are mainly controlled by the water regime, and (2) that the vegetative replacement under falling water levels proceeds very rapidly in the initial stages but more and more slowly through the shrub and forest types.

To provide the required input for the design of the wildlife productivity simulation model (see Appendix O), the major successional sequence and the estimated duration of each stage has been abstracted as follows:



*t = estimated number of growing seasons required for replacement to occur.

Clearly this represents a gross oversimplification of an extremely complex natural system; but, nevertheless, it is believed that the major vegetational categories are presented in the correct successional sequence and that the relative duration of the stages is of the right order.

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SECTION K

STATUS OF WATERFOWL ON THE PEACE-ATHABASCA DELTA

by

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INTRODUCTION

The waterfowl which breed and congregate on the Peace-Athabasca Delta constitute a direct and integral part of the livelihood of the native people of Fort Chipewyan and outlying Delta villages. The ducks, geese, and swans[1] and their eggs also provide food for predators, all of which comprise an ecologically sensitive, aesthetically attractive community of organisms. These predators, in turn, also provide food and income for local families.

Nationally and internationally, the Peace-Athabasca Delta is invaluable as a migration stopover for approximately 400,000 waterfowl en route to breeding areas in the Arctic, and 1,000,000 migrants to wintering areas across the southern part of this continent and extending into South America. Ducks raised in the Delta contribute to the hunters' fortune throughout western Canada and the three western flyways. More than 11,000 whistling swans (approximately 12 percent of the North American population) were counted in a single survey of the Delta during their fall stopover in 1971; as many as 25,000 have been recorded in the past (Banko and Mackay, 1964). For the once-endangered Ross' goose the Delta provides the major migration line between the prairie parkland region of central Alberta and Saskatchewan and the breeding grounds in the Perry River region of the Northwest Territories. In addition to waterfowl, a list of birds which occur in the Delta area includes such diverse species as snow buntings, robins, kingfishers, pine grosbeaks,

[1]See Appendix 1, this paper, for scientific names of animals mentioned in this report.

sora rails, great blue herons, snowy owls, peregrine falcons, and golden eagles.

The physiographic complexity - both in time and space - of the Peace-Athabasca Delta is the essence of its biological productivity. Simplification of that diversity, such as by stabilizing or permanently lowering water levels, eventually leads to a reduction in productivity. Stabilizing at relatively high water levels would result in lost waterfowl breeding habitat. Stabilizing at relatively low water levels would result in successional development of large areas of monotypic habitat with greatly reduced capacity for supporting wildlife. Animal communities thrive best along habitat interfaces, that is, in areas of optimum habitat interspersion (Leopold, 1933:129; Beard, 1953; Kadlec, 1962:268).

The changes in the water regime of the Peace-Athabasca Delta since 1968 generally have tended toward a relatively stabilized low water level situation, and aquatic-to-terrestrial succession has proceeded rapidly (Dirschl, 1972). Already, once-inundated areas have become mud flats, mud flats have become sedge-grass meadows, and meadows have been encroached by willows and tree seedlings. It is true that prolonged periods of relative drought have occurred in the past, but up to 1968 the floods had always returned, reversing the successional trend and maintaining the Delta's diverse and dynamic qualities.

This report provides: (1) results of 1971 waterfowl surveys, (2) a discussion of the Delta's wetland and waterfowl resources and

their local, national, and international implications, and (3) a discussion of the possible effects of existing and potential habitat improvement measures.

The waterfowl habitat evaluation has depended on the assistance of: G. H. Townsend, Ecological Coordinator, Peace-Athabasca Delta Project; W. G. Leitch, Ducks Unlimited; H. J. Dirschl, D. J. Nieman, G. H. Staines, and H. Weaver, Canadian Wildlife Service; P. Cruickshank, Peace-Athabasca Delta Project; H. Inglis, Shirley Helicopters; R. Sinotte, Ray's Flying Service; and S. Flett, J. Frazer, and F. MacKay of Fort Chipewyan. Special thanks are extended to M. Boyd and B. Johnson for their excellent assistance in field and office at Fort Chipewyan.

BACKGROUND

The Peace-Athabasca Delta is a complex and dynamic system of rivers, creeks, oxbows, potholes, and lakes interspersed with forested levees, sedge-grass meadows, and granitic Precambrian outcrops. Located in northeastern Alberta between 58° 15' and 58° 50' north latitude and 110° 40' and 112° 30' west longitude, this 2,000 square mile Delta has been, for centuries, the home of bison, moose, wolves, mink, fox, muskrats, beaver, waterfowl, and Indians. The Delta lies adjacent to the western edge of the tree-clad Precambrian Shield and in the sunset shadows of the Birch and Caribou Mountains. The Peace,Athabasca, Birch, and Fond-du-Lac Rivers scour their way through Rocky Mountains, Cretaceous hills, and Precambrian Shield to offer the Delta the vitality assimilated from 210,000 square miles of the continent.

The detailed hydrological mechanisms of the Delta have been described by Bennett (1971) and Kellerhals (1971). Since the damming of the Peace River, the satellite basins of the Delta, which occasionally were recharged by floods in the past, have been drying up at an approximate rate of 13 percent per year in terms of miles of shoreline.

Fluctuating water levels and the combination of low-relief deltaic alluvium, lacustrine sediments, and Precambrian outcrops with a climate that provides 100 frost-free days and an annual average of 16 inches of precipitation, have produced a vegetative community which includes many different representative species.

Additional information on the physical and biological characteristics of the Peace-Athabasca Delta can be found in Soper (1953), Raup (1935), Newcomen and Bajkov (1939), Bajkov (1939), Ross (1940), Charles (1947a, 1947b), Seper (1951), Smith et al. (1964), Campbell (1965), Sterling (1966), Novakowski (1967), Dirschl (1970) McCourt (1970), Surrendi and Jorgenson (1971), Nieman (1971), and Rienelt et al. (1971).

SPRING-STAGING WATERFOWL

Five sample counts of spring-staging and breeding waterfowl were conducted; May 4-9, 9-13, 15-18, 21-25, and 27-30. A Piper Super Cub airplane was used for counting over larger, more open lakes, and a Bell-47 B1 helicopter was used for counting over potholes, creeks, and small lakes. All shorelines flown over were classified, at the time of census, according to one of the nine

edge types (Table 1), and later measured on aerial photographs. Thus, waterfowl numbers for each count could be related to miles of shoreline of each habitat type.

Spring arrived early in the Delta in 1971. Breakup had begun by April 21: many of the shallow basins and creeks were open and water was flowing over the ice in the major river channels. Mallards were abundant at that time, both as flocks of pairs and as dispersed pairs exhibiting territorial behavior. Many pintails and goldeneyes were present, plus some green-winged teal, widgeon, and shoveler; one pair of lesser scaup was seen. Canada geese were present as pairs and small flocks, and snow geese were reported by April 27. Gulls, killdeers, kestrels, blackbirds, and robins had arrived by April 22.

The flocked duck totals for the five sample counts were: 48,417; 27,258; 8,806; 6,964; and 10,192. The last figure probably reflects an ingress of post-breeding birds, particularly mallards. The first count was regarded as the best single census for estimating densities of spring staging ducks (Table 1). Unidentified flocks and flocks of mixed species were apportioned according to identified ducks.

Densities ranging from 0 to 225 ducks per mile were observed for various areas and various habitat types in the Delta in 1971 (mean of means = 2.96 for divers, 28.20 for dabblers). The spring staging waterfowl population estimates were 432,500 ducks and 145,000 geese and swans. Of the duck population, the extrapolated estimate based on the densities was 373,310

Table 1. Estimates of spring-staging waterfowl densities and extrapolation of the 1971 population for the Peace-Athabasca Delta.

Edge Type	Drainage	Sample Miles	Avail. Miles Spring 1971	Dabblers: Average Density Per Mile	Dabblers: Range Of Densities	Dabblers: Est. Delta Pop.	Divers: Average Density Per Mile	Divers: Range Of Densities	Divers: Est. Delta Pop.
Emergent	R	96.00	1361.6	5.78	0-52.8	7,870	13.28	0-56.8	18080
	O	15.25	385.3	68.52	0-225.45	26,400	0.98	0-15.0	380
Immature fen	R	109.92	1203.4	76.21	0-371.42	91,710	0.17	0-12.66	200
	O	113.70	412.8	64.78	3.84-225.45	26,740	1.40	0-30.64	580
Mud flat	P	13.10	694.9	92.13	46.0-184.7	64,020	0	--	0
	O	192.05	269.0	59.01	6.82-136.0	15,870	1.08	0-9.75	290
Meadow	R	105.73	2364.8	19.7+	0-187.85	46,680	6.80	0-165.78	16080
	O	13.91	643.9	83.46	0.96-143.47	53,740	0.57	0-1.49	370
Low shrub	R	11.47	1930.4	13.86	0-49.05	26,760	6.01	0-33.15	11600
	O	48.10	664.2	6.77	0-6.12	4,500	0	--	0
Tall shrub	R	17.19	1107.9	5.46	0-26.66	6,050	7.38	0-17.14	8180
	O	22.14	316.3	2.89	0-6.10	910	1.12	0-2.72	350
Deciduous	R	0	344.1	3.0*	--	1030	4.0	--	1380
	O	(1.88)	73.6	2.5*	--	180	1.0	--	70
Coniferous	R	0	358.9	2.0*	--	720	2.5	--	900
	O	0	89.6	1.5*	--	130	1.0	--	90
Rock	R	(1.70)	128.4	0*	--	0	5.0	--	640
	O	0	20.2	0*	--	0	1.0	--	20
Totals						373,310			59,210
							432,520		

(Continued on next page.)

Table 1. Continued.

R = restricted or isolated drainage; O = open drainage

* Estimates based on adjudged attractiveness of the habitat relative to the calculated duck densities of other habitat types.

dabblers and 59,210 divers.

The 1971 investigations revealed that the edge types preferred by dabblers were mud flat, meadow, immature fen, and emergent (Table 1); the types preferred by divers were emergent, tall shrub, meadow, and low shrub; and the types preferred by geese and swans were mud flat and immature fen (Table 2). Transient spring waterfowl are not uniformly distributed throughout the available habitat of the Delta. Rather, flocks are found concentrated on sections of shoreline of various types; apparently, certain lakes and portions of lakes are favored. For example, 47 percent (44.6 miles) of the restricted-emergent edge sampled revealed no diving ducks; 18 percent (17.8 miles) supported less than the average density of 13.28 divers per mile (but more than 0); and 35 percent (33.6 miles) supported more than the average density.

The data do not tell us, however, to what extent the waterfowl would concentrate on other shoreline types if the aforementioned were absent or limited. From survey records collected by Ducks Unlimited personnel over the period 1938 to 1967, and under a variety of conditions (Table 3), it appears that Delta populations of fall-staging waterfowl are high to moderately high under all but extreme flood conditions, that is, when waters extend beyond normal shorelines into surrounding willow or forested habitat. It is reasonable to expect that the same limitation would apply to spring-staging birds. The limiting factor is the availability of a more or less open, dry land edge, and if any is present (particularly mud flat or immature

Table 2. Adjusted estimates of transient spring goose and swan densities, Peace-Athabasca Delta, 1971.

Edge Type	Drainage	Canada Geese	Snow Geese	White-fronted Geese	Ross' Geese	Whistling Swans	Total Geese and Swans
Emergent	Restricted	0.002	-	-	-	-	0.002
	Open	-	-	-	-	0.494	0.494
Mud flat	Restricted	2.40	3.24	-	-	0.783	6.42
	Open	53.03	107.31	5.77	20.12	20.37	206.60
Immature fen	Restricted	1.84	7.57	-	-	0.005	9.42
	Open	25.5	94.19	2.12	8.07	15.75	146.65
Meadow	Restricted	0.235	1.57	-	-	-	1.80
	Open	-	-	-	-	-	-
Low shrub	Restricted	-	3.24	-	-	1.00	4.24
	Open	0.03	-	-	-	0.04	0.08

Table 3. Summary of water conditions and waterfowl populations in the Peace-Athabasca Delta, recorded by Ducks Unlimited personnel during autumn surveys, 1938-1967.

Date	Observer	General Water Conditions	Waterfowl Population and Remarks
Aug. 22/38	Bartley/ Cartwright	Very low	Large population
Sept. 6/40	Cartwright	Moderately high	Very large: Claire-190,000; Mamawi 10,000
Aug. 17/47	Cartwright	Moderately low	Moderate: Claire-36,000. Count early.
Aug. 25/58	Cartwright/ Leitch	Moderately high	Large: Claire-102,000
Sept. 3/49	Cartwright/ Leitch	Moderately low	Very large: Claire-1,390,000; Mamawi-74,000--"feel that our estimates are low."
Aug. 25/50	Cartwright	Moderately low	Very large: Claire-532,000
Aug. 22/51	Cartwright	Moderately high	Moderate: Claire-low; Richardson-high
Aug. 26/52	Cartwright	Moderately low	Large
Aug. 28/53	Cartwright	Moderately low	Moderately large
Aug. 30/54	Leitch	Very high. Flooded Mamawi-Claire-Baril almost continuous	Very few ducks
Sept. 1/55	Leitch	Moderately high	Moderate: Claire-high;Athabasca-low (21,500 Canada geese on Claire)
Sept. 4/56	Leitch	Low to moderately low-"have never seen it better"	Moderate: Claire-Mamawi-low; Athabasca-high
Aug. 27/57	Leitch	High: "full but not flooded"	Few ducks. Mud bars lacking
Aug. 29/58	Leitch	Low-Richardson; moderately high elsewhere	Richardson-30,250 ducks; few ducks elsewhere

(Continued on next page.)

Table 3. Continued.

Date	Observer	General Water Conditions	Waterfowl Population and Remarks
Sept. 2/59	Leitch	Moderately high	Low to moderate
Sept. 3/60	Leitch	Very high	Very few ducks
Sept. 4/61	Leitch/ Sterling	Moderately low	Moderately low
Sept. 7/62	Sterling	Very high. Continuous water Ft. Chip to Lake Claire	Low to moderate
Sept. 5/63	Sterling	Low-Richardson; moderately high elsewhere	Moderate
Sept. 3/64	Sterling	High	Moderate: Richardson-16,000; Welstead-11,500
Sept. 1/65	Sterling	Very high	Moderately low: Claire-27,000; Welstead-5,200; Richardson-1,270
Aug. 30/66	Sterling	Very high	Moderately low: Claire-25,000; Welstead-38,400; Richardson-1,300
Aug. 31/67	Sterling/ Spelay	High	Low: Claire-11,500; Welstead-27,000 Richardson-1,200

fen), it is likely that enough will be present to accommodate all staging birds.

In most cases, the density figures derived were an average of high and low density areas. However, for some habitat types, such as restricted-drainage mud flat, the number of areas examined were few (three) even though numerous miles of shoreline were counted (13.1). These areas may or may not be an accurate representation of all such mud flat shoreline (of which there were 695 miles in the Delta). Because of small samples or lack of samples, the figures for deciduous, coniferous, and rock edge are estimates based on adjudged attractiveness of these habitats relative to the calculated duck densities of the other habitat types.

Possible errors in extrapolation of the population figures could result from:

(1) potential errors in determination of miles of habitat edge from 1970 aerial photos;

(2) possible changes in amounts of available edge between fall, 1970, and spring, 1971; and

(3) inapplicability of mean density estimates to all parts of the Delta.

The second consideration certainly applies to extrapolation of subsequent population segments (i.e., production, molters, fall staging). However, assuming these density and population estimates were reasonably accurate, it is possible to speculate

on minimum habitat requirements for potential populations and on optimum habitat conditions for spring-staging waterfowl. Maximum concentrations of dabblers were found on restricted-drainage immature-fen shoreline, at densities of up to 225 to 371 per mile. If such densities could be uniformly achieved, theoretically 1,000 to 1,660 miles of such habitat would be required to accommodate the dabbler population. At the average densities indicated for the above three habitat types (76, 69, and 65 respectively), 4,900 to 5,700 miles of such habitat would be required (only 2,000 miles were available in 1971). Although this may give us some idea of the magnitude of habitat requirements, it is really only a mathematical exercise. Our estimate of 432,500 ducks may be low compared to the number experienced in years when the continental population is high or when drought on the prairies forces birds further north. Also, differences between species of waterfowl indicate a need for a variety of habitat types rather than just those on which concentrations are highest. On the other hand, maximum possible concentrations are still unknown. Could there be concentrations exceeding 370 per mile? Fall counts certainly show that greater densities occur; however, food resources in fall are more plentiful and more ducks can be accommodated in that sense. Also, if the most "preferred" habitat types were limited or absent, to what extent would ducks concentrate on remaining types?

In order to satisfactorily accommodate current and potential spring-staging waterfowl populations, spring water levels should

be such that much of the margins of the large, open-drainage lakes be narrow bands of mud flat or immature fen. The period for such exposure would be from breakup until late May.

The optimum habitat conditions are considered to be those which provide an abundance of all shoreline types in order to accommodate all duck species and to provide simultaneous attraction for breeding birds. Conditions in 1971 may have approached this optimum; however, water levels, with advantage, could have been somewhat higher. Also, isolated or "perched" basins were not adequately recharged in 1971.

We are still unaware of all the characteristics which make some areas more attractive than others to the various segments of the waterfowl population. Habitat type, according to the system we have used, certainly does not always, or entirely, determine whether waterfowl will utilize a certain water body in preference to another. Therefore, particularly important waterfowl concentration areas should be pointed out, as it is these areas that should receive special attention in water management plans. These, in addition to bearing special attraction to waterfowl by way of physical characteristics such as water depth, water quality, food types and abundance, local topography, and juxtaposition of other water bodies, may also be attractive in a traditional sense. These areas included the north and east sides of Lake Claire, Lake Mamawi, the south shore of Lake Athabasca between Fort Chipewyan and Big Point Channel, Baril Lake, Lake 236, Welstead Lake, Lake 66, Lake 18 (North Egg Lake), Lake 94 (Big Lake), and channel 399 (Charles

Piver) (Fig. 1).

Previous research listed the north and east shores of Lake Claire, the shores of Mamawi Lake, and the Birch River Delta as significant concentration areas for waterfowl (Soper, 1933). The species found prevalent were mallard,shoveler, blue-winged teal, green-winged teal, baldpate, American goldeneye, pintail, bufflehead, ruddy duck, redhead, lesser scaup, and American coot. Of the Delta, Soper states:

> "Since time immemorial this part of the country has been a favourite stopping place of ducks, and geese during migration. It is more or less on the direct route of these birds northward bound from the Missouri-Mississippi drainage area. Prodigious flights of Canada and lesser snow geese, Ross' goose, whistling swan and many species of ducks formerly characterized the Peace-Athabasca Delta, and in a modified degree this holds true to the present. It is probably one of the greatest migrational 'clearing-houses' for waterfowl in the whole of northwestern Canada and there is a large section of it which favours breeding of certain species.
>
> "...In general it may be said that waterfowl are overwhelmingly more numerous in the small lakes, the sequestered reed-grown arms, bays and channels than a cursory examination of the larger lakes of this region would ever lead one to suspect." (Soper, 1933: 3,6)

The major concentration areas for spring waterfowl populations found in 1969 waterfowl surveys were the Athabasca Delta between Richardson Lake and Lake Athabasca and the marshes at the north end of Lake Claire (Dirschl, 1970).

Factors other than availability of specific habitat types may determine population densities of staging waterfowl in the Delta. These include the magnitude of the continental waterfowl population and the phenology of the spring season. A late spring may mean that many birds may bypass the Delta en route to more northern nesting areas. A dry spring on the prairies often forces birds further north and may thus increase both the breeding and non-breeding components in the Delta. In consideration of these factors, it may be more feasible and functional to attempt to determine minimum habitat requirements for spring-staging waterfowl, than to establish a range of expected population densities per habitat type. If water management decisions are directed toward optimizing waterfowl production, it is believed that habitat requirements for staging waterfowl will be satisfied.

Transient spring geese and swans were treated separately according to the maximum census per species (Table 2). As stated for ducks, turnover in utilization of Delta wetlands implies a greater significance than that indicated by a single count.

The only Delta breeding residents of this group were a small number of large Canada geese. Because of the small number, the large Canada geese have been included with the lesser Canada

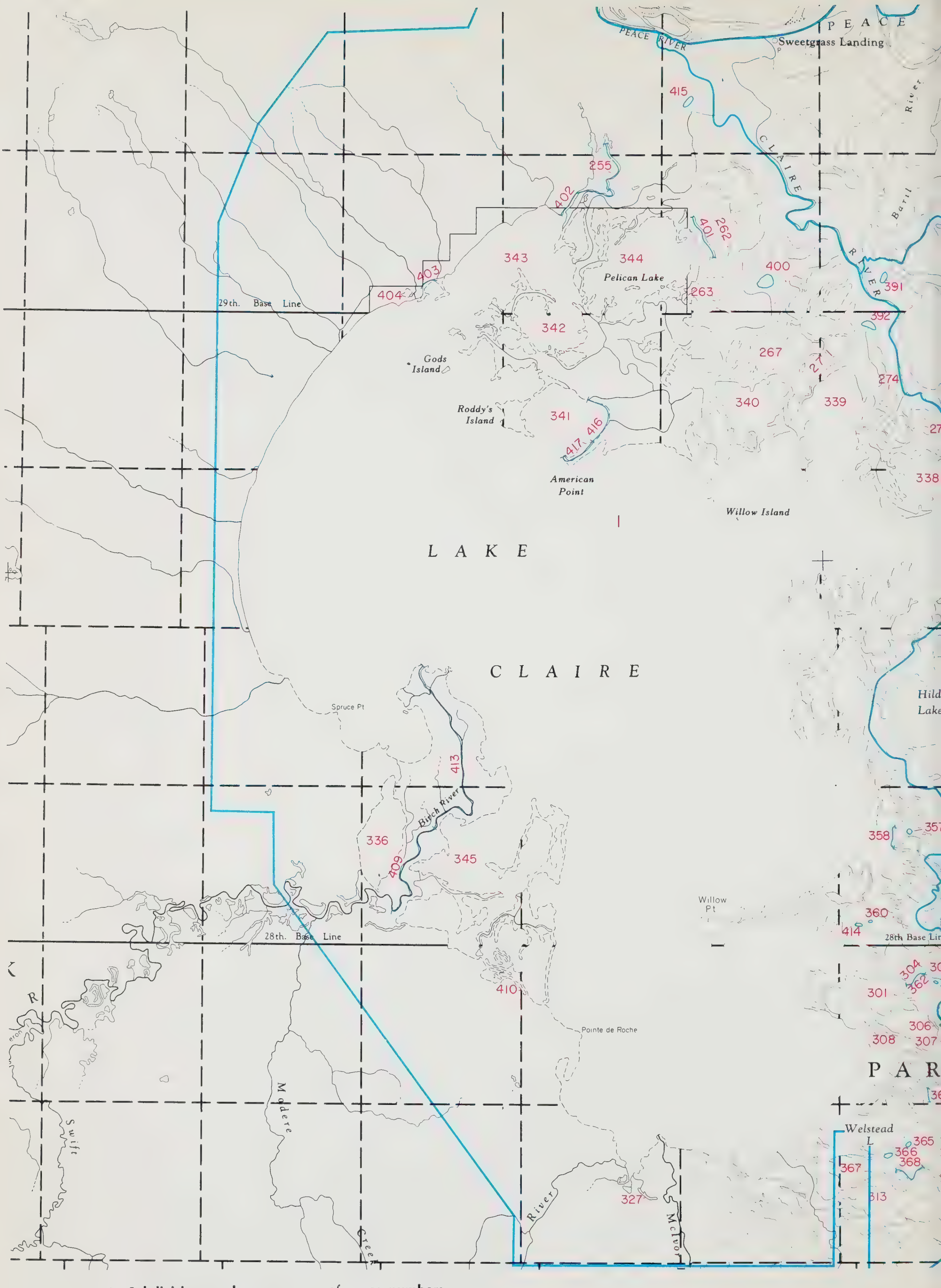
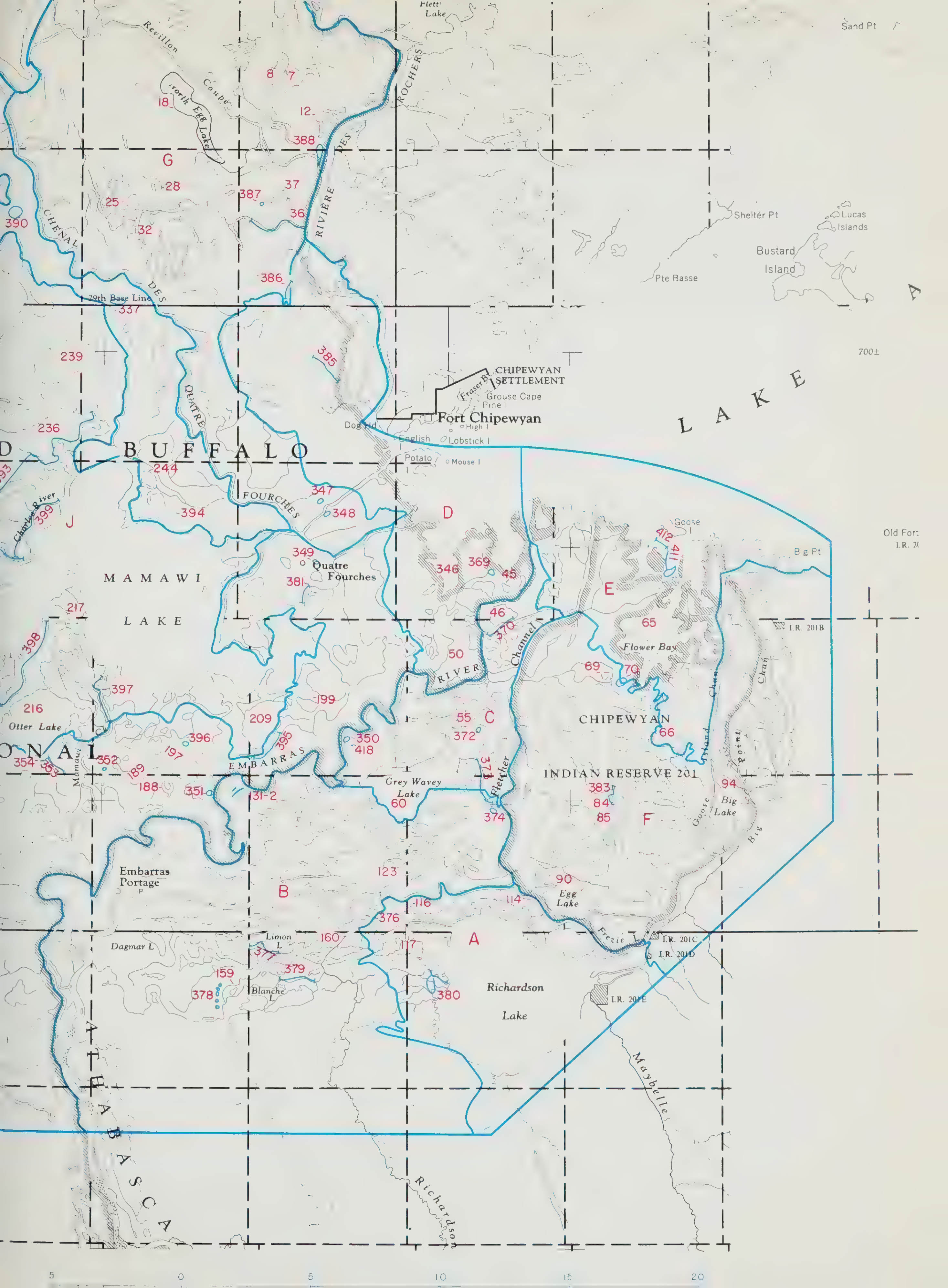


FIG. 1 Subdivisions and census area reference numbers



Flett Lake
Sand Pt
Revillon Coupé
North Egg Lake
ROCHERS
DES
RIVIÈRE
CHENAL DES QUATRE FOURCHES
29th Base Line
Shelter Pt
Lucas Islands
Bustard Island
Pte Basse
700±
CHIPEWYAN SETTLEMENT
Fraser B
Grouse Cape
Pine I
Fort Chipewyan
Dog Hd
High I
English
Lobstick I
Potato
Mouse I
LAKE
A
BUFFALO
Charles River
MAMAWI LAKE
Quatre Fourches
Goose
Old Fort I.R. 20
Big Pt
I.R. 201B
Flower Bay
Channel
RIVER
CHIPEWYAN INDIAN RESERVE 201
Island Chan
Goose Island
Point Chan
Big Lake
Big
Otter Lake
Mamawi Cr
EMBARRAS
Grey Wavey Lake
Fletcher
Embarras Portage
Egg Lake
Frezie L
I.R. 201C
I.R. 201D
I.R. 201E
Dagmar L
Limon L
Blanche L
Richardson Lake
Maybelle
Richardson
ATHABASCA
G
D
J
E
C
B
A
F
8 7 18 12 388 28 387 37 25 36 390 32 386 337 239 385 236 244 347 348 394 399 349 346 369 45 381 217 46 398 370 65 50 69 70 397 199 216 209 55 372 66 396 395 350 418 197 354 383 352 189 373 188 351 31-2 60 383 84 85 94 374 123 90 114 116 376 160 117 377 379 159 378 380
5 0 5 10 15 20

geese in the data analysis. The sample counts indicate that there was an ingress of large Canada geese at the end of May. These would most likely be sub-adult-nonbreeding and unsuccessful breeding geese at the beginning of the molt migration from further south (Sterling and Dzubin, 1967).

Snow geese and swans reached their maximum numbers earliest, May 9-13: 48,090 and 7,619 respectively; numbers of Canada and white-fronted geese were greatest May 15-18: 19,077 and 1,647 respectively; and Ross' geese reached their maximum May 21-25: 5,900. Only three of the ponds checked by heliccpter were utilized by geese and swans. Two hundred Canada geese and 150 swans were observed on pond no. 7. One pair of large Canada geese nested on pond no. 188, and one pair on no. 117. Large Canadas also nested in the bog-type habitat west of Lake Claire near Spruce Point.

The distribution of geese and swans was very notably clumped and non-random. Direct extrapolation of Delta populations cannot be made as has been done for spring-staging ducks. For example, the density figure for snow geese on restricted-drainage low-shrub edge is derived from a sample size of 13.07 miles of shoreline. All snow geese counted on such edge (800) were from a segment 0.7 mile long. However, on open-drainage mud flat and immature fen, which were sampled at rates of 54 percent and 69 percent respectively, the density estimates are probably accurate. The obvious propensity for use of mud flats and immature fen would seem, in fact, to make sightings along other edge types appear incidental. In order to compensate for the bias introduced by

small samples, adjustment factors were derived for those edge types sampled at a rate of less than 10 percent (i.e., all except open-drainage mud flat and immature fen). The adjustment factor was the quotient of the miles of edge on which birds were seen, divided by the miles of edge of that type sampled. Thus, for snow geese on restricted-drainage low shrub, the adjustment factor was 0.7/13.07 = 0.053. This changes the density estimate from 61.21 to 3.24 geese per mile. This adjustment assumes that the distribution of birds on the sampled shoreline is representative of the distribution on that type of shoreline throughout the Delta (i.e., 5.3 percent of restricted-drainage low-shrub habitat supports snow geese at a density of 61.21 per mile, or 100 percent of such habitat supports geese at a density of 0.053 x 61.21 = 3.24 per mile).

The 1971 Delta population estimate for all geese and swans, based on the adjusted density figures, was 145,000.

BREEDING WATERFOWL

Brood-count data were used to determine optimum breeding pair census periods for each species of duck. Counts conducted during those periods were used to derive breeding-pair densities for each edge type in open- and restricted-drainage systems.

Most transient waterfowl had passed through the Delta by the third week of May. The nest-initiation period of resident ducks ranged from mid-April to late June or early July (Table 4). Few Canada geese nested on the Delta, but there was evidence of some nesting by April 22. Seventy-four percent of observed successful

Table 4. Temporal distribution of nest initiation and hatching of ducks in the Peace-Athabasca Delta, 1971.

Nest Initiation/ Hatching Period	Percent of Successful Nests Initiated or Clutches Hatched															
	Mal	Pin	Gad	Wid	Sho	BWT	GWT	All Dabblers	LScp	Can	Red	GEye	Ring	Buff	Rud	All Divers
Apr. 13-20 May 15-22	1	4	0	0	0	0	0	0.4	0	0	0	0	0	0	0	0
Apr. 21-28 May 23-30	10	12	1	0	1	0	0	3.3	0	5	0	0	0	0	0	0.4
Apr. 29-May 6 May 31-June 6	20	18	0	0	6	0	0	6.4	0	10	0	3	0	0	0	1.2
May 7-14 June 7-14	14	33	0	6	6	1	3	8.0	0	32	31	30	3	14	0	7.3
May 15-22 June 15-22	30	19	5	37	48	15	24	28.5	6	39	38	27	28	36	40	16.6
May 23-30 June 23-30	10	10	17	38	29	34	41	27.0	16	7	15	24	41	19	40	18.4
May 31-June 7 July 1-8	9	4	37	11	8	22	11	13.1	36	7	8	13	22	31	0	28.6
June 8-15 July 9-16	5	0	31	6	2	20	15	9.9	24	0	0	0	3	0	10	15.5
June 16-23 July 17-24	1	0	9	2	0	8	6	3.4	18	0	8	3	3	0	10	12.0
Total broods observed	146	57	65	122	147	103	124	764	282	41	13	30	32	42	11	451

K19

dabbler clutches and 44 percent of observed successful diver clutches were hatched by June 30. The only species showing evidence of renesting was the mallard (and, perhaps, bufflehead) with one nesting peak in late April and a second, more pronounced peak, in mid-May.

Mean dabbler breeding pair-densities on sampled shorelines ranged from 0.2 to 18.4 per mile in 1971; diver pair densities ranged from 0.0 to 8.7 per mile (Table 5). Dabblers apparently preferred meadow, emergent, and tall-shrub shoreline types. In all cases except meadow and emergent shoreline, restricted drainage systems were preferred to open systems. Diver pairs preferred tall-shrub, emergent, and low-shrub edge types, and in all cases, restricted-drainage systems revealed greater densities than open systems. Extrapolated estimates of Delta breeding-pair populations, with consideration of the same possible error sources as discussed for spring-staging ducks, were 119,900 dabblers and 42,800 divers (total of 162,700 breeding pairs). With a delta area of 2,000 square miles, the overall breeding-pair density would be 162,700 / 2,000 = 81 pairs per square mile. In comparison, Stoudt (1969:125, 129) presented a range of values of 65 to 185 pairs per square mile for prairie pothole habitat.

Estimates of production for the portion of the Delta more or less equivalent to subdivisions H, I, J, and K combined (Fig. 1), were calculated in a preceding study (Sterling, 1966:3). Using shoreline measurements derived from aerial photos, and average figures of breeding pairs of waterfowl of 13 and 30 per

Table 5. Indicated breeding pairs of ducks per mile according to optimum census per species, Peace-Athabasca Delta, 1971.

		DABBLERS								
Edge Type	Drainage	Mal	Pin	Gad	Wid	Sho	BWT	GWT	Total Dabblers	Adjusted Dabblers
Emergent	Restricted	4.1	1.0	0.5	1.0	1.8	1.4	1.3	11.1	13.5
	Open	3.1	3.1	0.0	0.6	2.6	1.1	1.1	11.6	14.1
Immature fen	Restricted	1.6	1.8	1.2	0.6	2.7	0.3	1.0	9.2	9.3
	Open	3.2	1.4	0.6	0.8	1.5	0.3	0.6	8.4	8.5
Mud flat	Restricted	1.7	0.5	1.8	1.4	2.5	0.1	1.1	9.1	8.3
	Open	1.8	1.2	0.3	0.5	0.9	0.1	0.4	5.2	3.7
Meadow	Restricted	3.5	1.7	0.8	1.4	3.1	1.7	1.8	14.0	16.3
	Open	5.3	2.7	0.6	1.3	3.7	1.2	1.0	15.8	18.4
Low shrub	Restricted	3.7	0.8	0.2	0.3	1.0	0.2	1.9	8.1	9.3
	Open	1.4	0.3	0.2	1.4	0.5	0.2	0.9	4.9	5.6
Tall shrub	Restricted	2.6	0.6	0.4	1.2	2.4	2.0	1.6	10.8	12.0
	Open	2.2	0.4	0.3	0.3	1.2	0.7	1.1	6.2	6.9
Deciduous	Restricted	-	-	-	-	-	-	-	5.0	5.6
	Open	0.0	0.0	0.0	0.5	0.0	0.0	2.1	2.6	2.9
Coniferous	Restricted	2.3	-	0.0	0.0	0.0	0.0	0.8	3.1	3.3
	Open	-	-	-	-	-	-	-	1.0	1.1
Rock	Restricted	1.9	0.0	0.0	1.1	0.0	0.0	1.4	4.4	0.9
	Open	-	-	-	-	-	-	-	1.0	0.2

(Continued on next page.)

Table 5. Continued.

Edge Type	Drainage	DIVERS LScp	Can	Red	GEye	Ring	Buff	Rud	Total Divers	Adjusted Divers
Emergent	Restricted	3.9	1.8	0.5	0.4	0.6	0.2	0.6	8.0	6.1
	Open	0.1	0.2	0.1	0.2	0.1	0.0	0.0	0.7	0.5
Immature fen	Restricted	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.3
	Open	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1
Mud flat	Restricted	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.2	0.2
	Open	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Meadow	Restricted	2.5	0.2	0.3	0.3	0.1	0.1	0.2	3.7	3.8
	Open	1.0	0.2	0.3	0.0	0.0	0.0	0.0	1.5	1.6
Low shrub	Restricted	3.0	0.2	0.4	0.0	0.3	0.2	0.4	4.5	5.2
	Open	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.3	0.3
Tall shrub	Restricted	4.5	0.8	0.3	0.7	0.4	0.6	0.6	7.9	8.7
	Open	1.4	0.0	0.1	0.0	0.0	0.2	0.0	1.7	1.9
Deciduous	Restricted	-	-	-	-	-	-	- *	4.0	4.4
	Open	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coniferous	Restricted	0.8	0.0	-	-	0.8	2.3	0.0	3.9	4.3
	Open	-	-	-	-	-	-	- *	0.5	0.6
Rock	Restricted	3.4	0.3	0.0	0.2	0.0	0.9	0.2	5.0	1.0
	Open	-	-	-	-	-	-	- *	0.2	0.0

* For those habitat types for which no sample was taken, an estimate of pair densities was made on the basis of adjudged attractiveness of the habitat relative to other habitat types.

K2

mile (unimproved and improved conditions), estimates of 37,800 to 87,240 breeding pairs were calculated.

A complex distribution and interspersion of all habitat types present in the Delta is essential to promoting successful pair dispersal and production for a variety of waterfowl species (Table 5). The presence of all types should be ensured although the importance of some exceeds others.

Indicated pair densities were calculated for each duck species and adjusted values were computed for the diver and dabbler groups. These adjustments (Appendix 2) were based on estimates of:

(1) Observability, which depends on habitat type, plumage characteristics,, and behavior, and, in this case, assumes that helicopter and airplane censusing methods (as well as different observers) are equally efficient. (The weaknesses of this latter assumption are obvious, and are discussed by Bowinski [1958:74-77]. Observability also depends on other factors, such as weather and direction of light, which are too variable and immeasurable to allow for compensation in calculations.

(2) Turnover in use of habitat sites by breeding pairs (Sowls, 1955:57).

(3) Presence of non-breeding birds.

(4) A bias resulting from subconscious selection of areas likely to support ducks. This bias applied only to

helicopter surveys and only emergent, meadow, and low shrub habitats.

(5) Additional pairs represented by unidentified ducks. Ratios of unidentified to identified indicated pairs ranged from an average of 1:28 for helicopter counts to 1:14 for airplane counts. Thus, the census results could be greater by 3.6 percent to 7.2 percent. Unidentified pairs were not apportioned to the different species because species visibility varies (Rowinski, 1958; Martinson and Kaczynski, 1967) and because amounts of censused habitat of each type were not equal.

(6) The correction factor for rock (-80 percent) was based on the small sample size and on the fact that ducks seen on rock edge were probably there because of proximity to some other edge type. (For further discussion of factors affecting aerial waterfowl surveys, see Martinson and Kaczynski (1967) and Diem and Lu (1960).

The significance of the aforementioned habitat types has been based on the relationship of bird densities to the immediate, apparently effective (i.e., having an influence on bird use) edge. It should be realized that, in the case of breeding pairs, habitat types adjacent to this edge are also influential in determining bird use. This is more applicable to dabblers, which may nest at a considerable distance from water, than to divers, which generally nest over, or immediately adjacent to water. Therefore, when tall shrub is revealed as an attractive

shoreline type, according to our methods, its real significance may be partially related to the fact that tall shrub is often on a levee adjacent to a grass meadow, the latter being excellent resting habitat--this in addition to the fact that levees with intermittent shrub cover provide secure and attractive nest sites.

The significance of restricted-drainage systems as compared to open systems (Table 5) has important water management implications. Restricted water bodies not only support the greatest pair and production densities, but also provide a much greater proportion of available shoreline mileage throughout the Delta (at suitable water levels). Also, once filled, they are not generally subject to the same water level fluctuations as open drainage systems; and, therefore, waterfowl nests have a greater success potential.

Optimum habitat conditions for production require that the aforementioned variety of types be maintained throughout the period between late April and the end of July, or at least May 1 to July 15. Moderate recession of water levels during the latter part of this period would not significantly reduce nesting success; however, rising water levels would cause losses at varying rates depending on the magnitude and timing of such increases. Minor increases and decreases would only affect open-drainage systems. Divers generally would be more susceptible than dabblers to nest destruction or brood loss by water level fluctuations.

Other researchers have also noted varying effects of water level fluctuations on duck production. Newcomen and Bajkov (1939: 5, 7, 17) regarded the drainage of spring floods from the Athabasca Delta as a waste:

> "During the last four years (1935-1939), the spring floods have drained out into Lake Athabasca, doing untold harm to the Muskrat and Beaver population. Although the waterfowl conditions both as regards nesting and population are still good; there is a marked dropping off in late years . . . and the belief is that they will continue to decrease year by year. It is therefore evident that systematic policy of water conservation is urgently required, and also desired by the local inhabitants."

> "...The entire area abounds in good cover and feed. Unfortunately, during the last two or three years, considerable loss has been caused to the newly hatched birds by the lack of water especially in the Blanche, Mud, and Dagmar Lakes area...."

In 1964, a dam on the Chenal des Quatre Fourches was proposed (Campbell, 1965); the plan was considerably more energetic than that of Charles (1947b). The new plan called for 75 miles of dyke, compartmentalization of the Claire-Mamawi area, and tertiary developments within compartments. Although the plan was not executed, valuable information regarding the Delta was provided in this and a complementary report by Sterling (1966).

One of the important assertions of both those reports was that the waterfowl production of the Delta was far below its potential because of early summer floods.

As already mentioned, spring water conditions must simultaneously provide attraction for staging and breeding birds. In order to provide optimum conditions for both population segments, mud flat-R[1], meadow-O, immature fen-R, and emergent-O and R should be present, along with tall shrub-R, meadow-R, and low shrub-R. All of these conditions cannot be met simultaneously throughout the Delta. In order to provide these when and where they will benefit waterfowl most--namely in restricted-drainage basins--water levels must be raised early in spring. Such a regime would eliminate much of the mud-flat and immature-fen shoreline apparently preferred by staging dabblers, geese, and swans. A compromise could be achieved temporally or spatially. Water levels could be raised by May 15-20, thus accommodating most of the staging birds while providing for flooding of perched basins before the majority of nests were initiated. On the other hand, water levels could be raised at breakup, but only to a point of flooding some of the perched basins while leaving others at levels which would provide for mud flat and immature fen edge. The temporal arrangement would be preferred, mainly because it would allow for a better distribution of preferred habitat types.

[1] R=restricted-drainage system; O=open-drainage system.

WATERFOWL PRODUCTION

Two methods of estimating production were available from the 1971 field data. First, one can use the breeding pair census data, making certain assumptions regarding success, brood size, and relationships of breeding pairs to broods to habitat types. For example, in other studies (Hammond, 1958:357; Lacy, 1959:74) it has been considered reasonably accurate to assume that 50 percent of the breeding pairs produce an average brood of six. (This average brood-size figure concurs with our findings for Class III broods on the Peace-Athabasca Delta in 1971.) Thus, the breeding-pair figure is multiplied by three to estimate production.

The second method available for estimating production was to make a count of broods and apply average brood sizes and knowledge of age classes. In this case, assumptions involve observability of broods in different habitat types (more so than pairs), comparative observability of different species, and time of day of counts in different areas of the Delta. Because of brood movement and because of the low proportion of broods actually seen, brood counts generally are not considered to be as good as pair counts as indicators of specific habitat productivity (Rowinski, 1958:88).

Production-density estimates were computed using both pair-count and brood-count data (Figs. 2 & 3). Dabbler production distribution reveals the above-mentioned possibilities, namely unobserved broods (the overall mean density is lower for brood

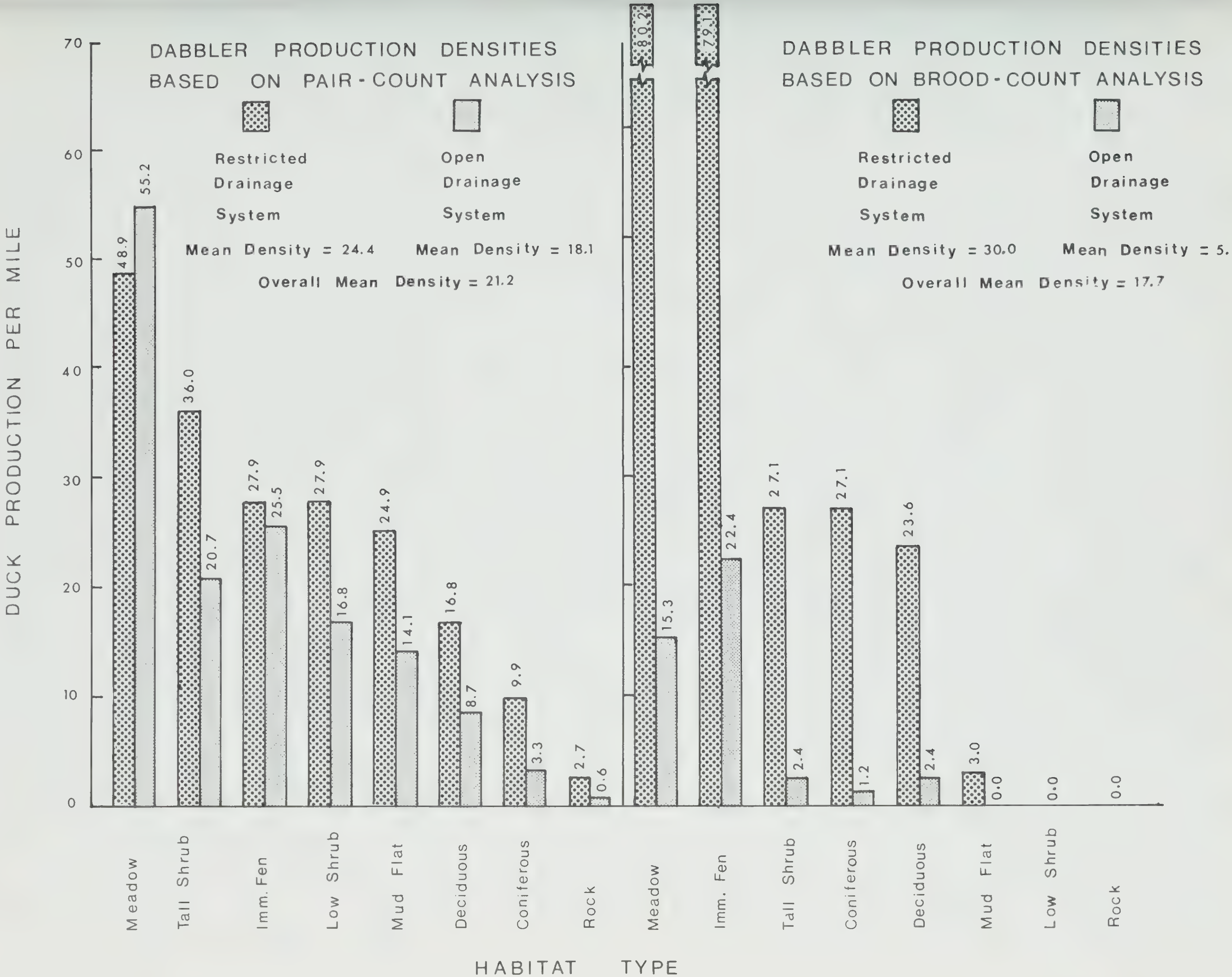


Fig. 2 1971 dabbling duck production-density estimates based on sample pair counts and brood counts, Peace-Athabasca Delta.

count analysis), and brood movement (in this case toward meadow and immature fen habitats -- Fig. 2). However, for divers, production-density estimates based on brood data were approximately twice as great as those based on pair data (Fig. 3). Also, indications of brood movement are not nearly as pronounced as for dabblers. The first of these phenomena may, at least partially, be explained by the fact that diver broods, because of behavioral characteristics, are more observable than dabbler broods. That is, dabbler broods generally seek cover when disturbed whereas diver broods often move out into open water. (However, an attempt already had been made to compensate for this fact in the adjustment factors for brood observability, Appendix 3.) Secondly, dabbler broods are more frequently produced adjacent to shallow water areas and may be forced to move to more permanent, deeper water, whereas divers, more frequently produced along streams and on deeper ponds and lakes, are not under such pressures to move.

The greater diver-production densities, based on brood data as compared to pair data, are difficult to explain. Broods generally are not considered more observable than pairs. One possible explanation lies in the fact that pair data were obtained from a considerably larger sample--a sample which included much more mud flat and immature fen, especially around larger lakes. This explanation does not apply to tall shrub, however, where the sample size was the same in both instances. The possible biases of sample size superimposed on brood movement inhibit accurate density estimates.

Nevertheless, we must use the best data available, interpreting it with the above possibilities in mind. Obviously, if brood-count figures exceed pair-count production estimates, the former must be more reliable; therefore, the brood-count analysis has been used for diver production estimates. For dabblers, however, the mean production densities estimated by both methods were similar, while the relative distribution, according to habitat types, changed considerably. In the case of dabblers it was more acceptable to utilize the pair data to estimate production densities. Table 6 summarizes the density estimates accordingly, and provides production estimates for the Delta based on available habitat in the spring of 1971.

MOLTING WATERFOWL

Molting-waterfowl counts were made via helicopter for areas of emergent vegetation, and via airplane for open shorelines or shorelines with emergent edge. The average transect width was 150 ft. Three counts, of varying intensity, were made: June 29, July 8-15, and July 24-27. The distribution and density of molting waterfowl is not so much a function of shoreline as it is of wetland area. Therefore, molting counts were related to acres of open water or emergent vegetation.

The molting population of the Delta includes post-breeding and non-breeding resident birds and immigrants from surrounding lakes and marshes. It also includes sub-adult, non-breeding and unsuccessful-breeding geese and post-breeding ducks from areas considerably south of the Delta (Sterling and Dzubin, 1967;

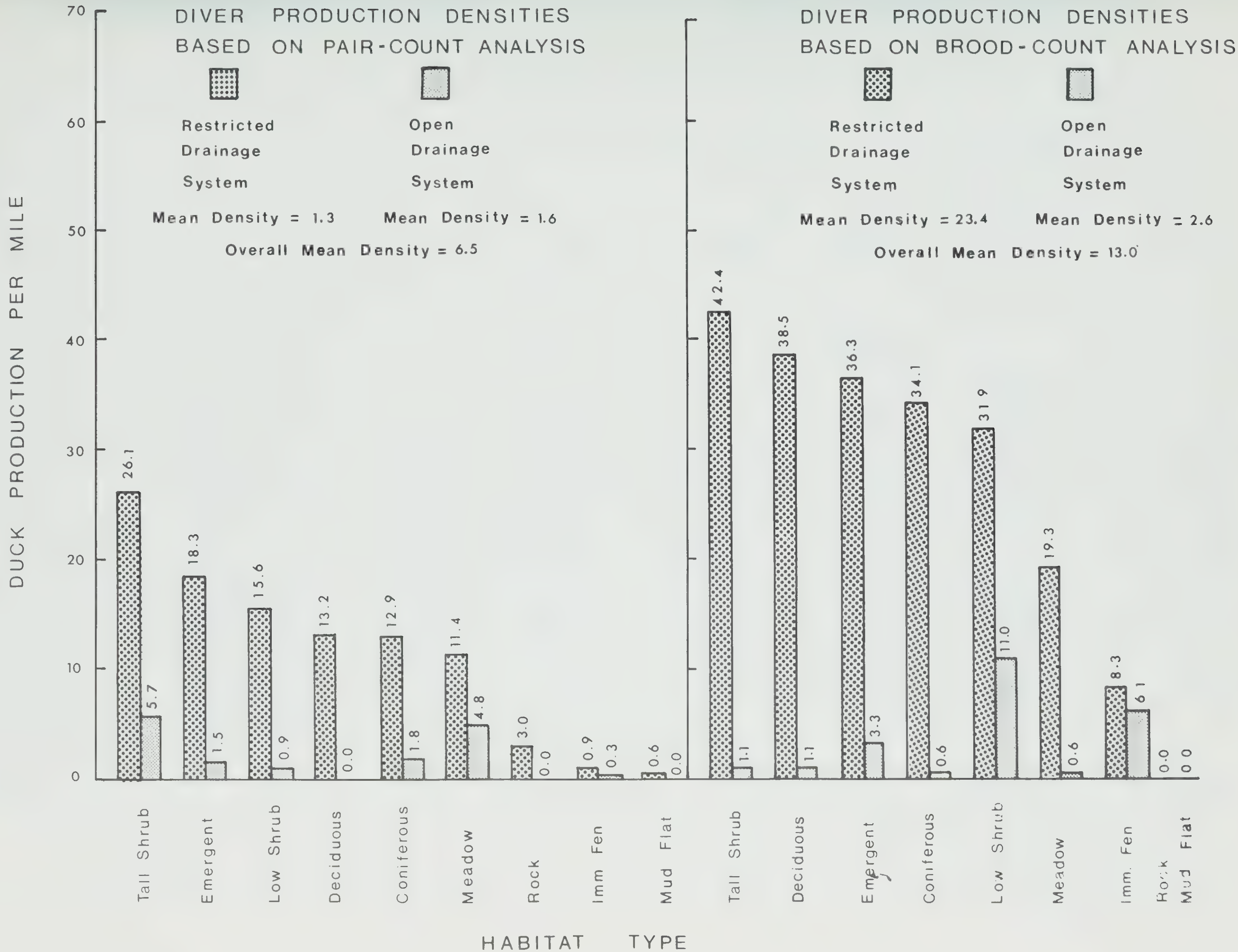


Fig. 3 1971 diving-duck production-density estimates based on sample pair counts and brood counts, Peace-Athabasca Delta.

Table 6. Summary of production density estimates and total production of waterfowl in the Peace-Athabasca Delta, 1971.

		Production Density Estimates		Miles of Available Edge, Spring, 1971		Delta Production Estimates	
Edge Type	Drainage	Dabblers	Divers	Dabblers	Divers	Dabblers	Divers
Emergent	Restricted	-	36.3	-	1361.6	-	49,426
	Open	-	3.3	-	385.3	-	1,271
Mud flat	Restricted	24.9	0.0	736.9	694.9	18,349	0
	Open	14.1	0.0	281.0	269.0	3,962	0
Immature fen	Restricted	27.9	8.3	1348.7	1203.4	37,629	9,988
	Open	25.5	6.1	455.9	412.8	11,625	2,518
Meadow	Restricted	48.9	19.3	2559.2	2364.8	125,145	45,641
	Open	55.2	0.6	688.5	643.9	38,005	386
Low shrub	Restricted	27.9	31.9	1988.0	1930.4	55,465	61,580
	Open	16.8	11.0	692.8	664.2	11,639	7,306
Tall shrub	Restricted	36.0	42.4	1127.6	1107.9	40,594	46,975
	Open	20.7	1.1	320.9	316.3	6,643	348
Deciduous	Restricted	16.8	38.5	346.7	344.1	5,825	13,248
	Open	8.7	1.1	75.8	73.6	659	81
Coniferous	Restricted	9.9	34.1	360.3	358.9	3,567	12,238
	Open	3.3	0.6	90.1	89.6	297	54
Rock	Restricted	2.7	0.0	131.9	128.4	356	0
	Open	0.6	0.0	20.7	20.2	12	0
Total						359,772	251,060
						610,832	

Dirschl, 1970:53). The total number of waterfowl utilizing the Delta as a molting area during one annual cycle will be considerably greater than that observed in a single census: there is significant interspecies and intraspecies phenological overlap through the molting season. For example, some mallards may have regained flight following their molt at the time that blue-winged teal are just beginning to molt. Meanwhile, some renesting mallards may have had their molt period retarded, coinciding with the blue-wings. The assessment of molting populations is further complicated by the possibility that Class III young ducks were sometimes mistaken for molting adults. Also, the molting period overlaps with the fall concentration period when post-molting birds arrive from areas outside of the Delta.

Under these circumstances, the best direct estimate of molting populations that can be derived is one from a sample count which reveals the maximum density of molting birds. Actually, a more accurate estimate would be derived by obtaining, for each species, the maximum of a series of counts (as was done for breeding pairs). However, due to the drab and mottled eclipse plumage of molting ducks, identification from the air cannot extend accurately beyond the categories of dabblers and divers.

Available habitat, beyond a reasonable minimum, has not been considered a factor limiting molting populations of geese (Canadas) on the Delta. Such populations have been considered a function of production and of the number of immigrant non-breeding and unsuccessful-breeding geese.

Three habitat categories have been used in the analysis:

(1) open water (shorelines),

(2) marginal emergents and the open water immediately adjacent, and

(3) emergent, that is, areas of continuous emergent cover or emergents interspersed with open water.

There is an obvious, but indeterminate, observability bias between counts cf molters in open water as compared to emergent cover, and between dabblers as compared to divers. There are few, if any, records of attempts to determine adjustment factors to compensate for relative observability. Dirschl (1970:50) recorded an average molting waterfowl density of 41.5 per mile; however, no adjustment factors were applied for different habitat types. Estimated adjustment factors were based on considerations of bird behavior and cover types in the Delta (Table 7). The last count was the most extensive (largest sample) and yielded the highest densities of molting waterfowl (Appendix 4).

Molting-duck densities on sampled areas ranged from zero to 30 per acre for dabblers and zero to 13 per acre for divers. Marginal-emergent cover of open-drainage lakes was most frequently used by divers.

Distribution of concentrations of molting ducks in 1971 was similar to that observed by Dirschl in 1969 (Dirschl, 1970:51).

Table 7. Estimated adjustment factors for waterfowl molt-count results, Peace-Athabasca Delta, 1971.

	Adjustment Factors	
Habitat Type	Dabblers	Divers
Open water	1.0	1.0
Marginal emergent	1.6	1.3
Emergent	1.8	1.6

Favored areas were the lakes along the southeast side and north end of Lake Claire, the Birch River Delta, and portions of Mamawi Lake.

Notable concentration areas for molters in 1971 included the lakes along the southeast side of Lake Claire (301, 304, 305), portions of the north end of Lake Claire (402), the Birch River Delta (345), Lake 239, and much of Mamawi Lake.

It has been generally agreed that ducks seek areas of emergent cover during the flightless period; however, the range of density values (Table 8) suggests that habitat type was second in importance to location of lakes--and perhaps a combination of other factors, such as water depth and availability of aquatic foods--in determining the distribution of molting ducks. These location preferences were also observed by Dirschl (1970:52-3). The marginal-emergent shorelines of open-drainage lakes appear to be the preferred molting areas for dabblers (adjusted mean density = 16 per acre). The extraction of this figure is based almost entirely on a sample of 800 acres of such habitat in Lake Mamawi. It was also determined that 30+ dabblers per acre were accommodated on the open water of a restricted-drainage lake. This figure was derived from a sample of 71 acres of such habitat in Lake 305. It appears that the Delta could have accommodated many more molting waterfowl than it did in 1971, but that certain lakes or groups of lakes have a particular (perhaps traditional) attraction superceding the presence or absence of emergent cover.

Table 8. Summary of molting duck density estimates, Peace-Athabasca Delta, 1971.

Habitat Type	Drainage	Sample Size (acres)	Total Dabblers	Total Divers	Dabblers Per Acre			Divers Per Acre		
					Range	Observed Mean	Adj. Mean	Range	Observed Mean	Adj. Mean
Open	Restricted	1601.8	10,424	139	0.84-30.35	6.50	6.50	0.00-0.99	0.08	0.08
	Open	930.8	4,656	671	0.25-22.41	5.00	5.00	0.00-12.55	0.72	0.72
Marginal emergent	Restricted	960.7	326	9	0.02-1.07	0.33	0.53	0.00-0.01	0.01	0.01
	Open	1465.9	13,336	90	1.00-15.84	10.00	16.00	0.00	0.06	0.08
Emergent	Restricted	469.1	896	22	0.09-10.62	1.91	3.44	0.00-0.25	0.04	0.06

The best use which might be made of the data in Table 8 may be the determination of minimum habitat requirements for potential molting populations. Based on crude estimates from 1971 observations, a molt population of 500,000 ducks is more than is likely to be achieved in the Delta. At 30 ducks per acre, 17,000 acres of suitable water habitat (with or without emergents, but with adequate aquatic food and preferred depths) is required to accommodate a population of that size. It is important to note that we may be overlooking a requirement or requirements of molting-duck concentrations. Such requirements may mean that much more of a particular habitat type is necessary than is actually utilized at a given time. Also, the choice of specific concentration sites may change from year to year as food resources are locally depleted or water levels fluctuate. It must not be forgotten, as well, that brood water requirements must be met at the same time as molting-waterfowl requirements.

Optimum habitat conditions would require that the water regime would be one of static or slightly reduced water levels. The period of concern follows and is partly coincident with that of breeding and production. This is the period (June 1 to August 15) of growth of emergent vegetation. Increases in water levels could flood out nests while pronounced reductions would result in immediate loss of marginal emergent habitat. For open-drainage systems this means that, following early high water levels and subsequent to immediate drawdowns (when necessary), water levels should not fall more than 0.5 to 1.0 ft before August. For restricted-drainage systems, water level reductions

will depend on evapotranspiration rates for individual water bodies, except for years in which they are flooded above their full supply level.

FALL-STAGING WATERFOWL

As was done for spring-staging waterfowl, a series of counts was made of the fall-staging birds in order to detect immigration, emigration, and peak populations. Counts were made August 9-19, August 30-September 4, September 16-18, September 30-October 3, and October 12-14. Sample size ranged from 305.2 to 384.6 miles. The last count was made over a somewhat different route from the preceding four in order to include known concentration areas of geese and swans. All counts were made from a Piper Super Cub airplane.

By the time the late-nesting species were initiating their clutches, drakes of the early nesters were beginning to flock for molting; and post-breeding birds from elsewhere were beginning to concentrate on the Delta. These concentrations continued to increase through June, July, and August. From mid-August through October, waterfowl were moving into and out of the Delta. According to our sample census figures, the maximum concentration of fall-staging ducks occurred between August 30 and September 4; the maximum for geese occurred during the second week of October.

Freeze-up and the coming of "winter" was sudden in the Delta, as it was throughout much of the prairie provinces. Ice covered many of the small ponds on October 24. Freezing temperatures,

snow, and strong northwest winds between October 25 and 27 forced most waterfowl out of the Delta. The overnight low, October 28, was -5°F.

Behavioral characteristics dictate that numbers of dabblers, geese, and swans should be related to shoreline miles, while diver densities be expressed on an area basis.

Many of the considerations discussed in the analysis of spring-staging populations also apply to fall-staging waterfowl, especially with respect to clumped, non-random distribution and turnover, in utilization of Delta wetlands. Some characteristics make assessment of fall populations easier. Late fall flocks are often larger, more discrete units and more mono-specific than spring flocks. Also, confusion with breeding birds is not a problem.

Factors other than availability of specific habitat types may determine the staging waterfowl population densities, e.g., magnitude and nesting success of the northern breeding population, and autumn phenology.

On sampled areas, mean densities of fall-staging waterfowl ranged from 2 to 1,142 per mile for dabblers, 0.03 to 0.20 per acre for divers, and 0 to 105 per mile for geese and swans. Mud flat, immature fen, and emergent shorelines were preferred by dabblers, geese, and swans; emergents and the open water of rivers were preferred by divers.

An earlier study revealed that fall-staging dabblers preferred

the mudflats of Lakes Claire and Mamawi, while divers preferred the larger lakes of the Athabasca Delta (Nieman and Dirschl, 1971).

One to 1.5 million waterfowl might be expected to utilize the Delta as a staging area in the fall (not simultaneously). At maximum waterfowl densities, as observed in 1971, at least 200 to 300 miles of shoreline of the preferred types would be required to accommodate such a population at one time.

The indicated optimum water regime, relative to preceding water levels, would be one of minor reductions to ensure the maintenance of considerable marginal emergent cover, as well as an abundance of mud flat and immature fen shoreline (such margins being 20 to 200 ft. wide).

The areas of outstanding concentrations of fall-staging waterfowl included most of the north and east shores of Lake Claire, the Birch River Delta (345), lakes along the southeast side of Lake Claire (Welstead, 301, 304, 305), Mamawi Lake, and the south shore of Lake Athabasca.

The five fall counts demonstrated a temporal population pattern (Table 9). While the fifth count followed a modified route, it is believed that the indicated direction of population fluctuations was, in fact, real; that is, the total duck population declined and the total goose and swan population reached a maximum. There is evidence of two concentration peaks for mallard, pintail, gadwall, green-winged teal, and Canada geese; however, this may have been a reflection of the modified

Table 9. Waterfowl fall staging census summary, Peace-Athabasca Delta, 1971.

Census Period	Sample Size (Miles)	DABBLING DUCKS Mal	Pin	Gad	Wid	Sho	BWT	GWT	Unid	Total
Aug. 9-19	384.6	2925	2620	78	1475	910	372	1448	97117	106945
Aug. 30-Sept. 4	384.6	4179	3772	669	2129	497	425	8173	149491	169335
Sept. 16-18	374.8	1246	1094	310	2072	91	6	1164	129723	135706
Sept. 30-Oct. 3	374.8	3103	3129	32	1532	3	0	2761	122066	132626
Oct. 12-14	305.2	8860	53	10530	58	0	0	642	30697	60840

Census Period	Sample Size (Miles)	DIVING DUCKS Scp	Can	G.E	Ring	Red	Buff	Rud	Scot	Unid	Total
Aug. 9-19		505	75	34	0	2	4	6	3	40	669
Aug. 30-Sept. 4		3083	15	14	5	0	5	9	0	854	3985
Sept. 16-18		772	69	16	0	1	2	10	0	3902	4772
Sept. 30-Oct. 3		634	448	30	0	13	28	2	0	2466	3621
Oct. 12-14		4	0	22	0	0	14	0	0	76	116

Census Period	Sample Size (Miles)	GEESE AND SWANS Canada	White-front	Snow	Ross	Total	Swans	Geese and Swans
Aug. 9-19		434	0	0	0	434	0	434
Aug. 30-Sept. 4		7334	0	6	0	7340	8	7348
Sept. 16-18		5571	465	28	0	6174	718	6892
Sept. 30-Oct. 3		4505	0	1841	0	6346	3852	10198
Oct. 12-14		7245	56	8858	0	16149	11481	27630

sampling route of count #5 (this applied to mallards and Canada geese, but not gadwalls), or a movement of birds within the Delta between counts. Because of the high proportion of unidentified to identified ducks, it was considered unwise to apportion unidentified birds according to percentages of those identified. Therefore, the maximum total counts for the dabbler and diver groups were used to estimate population densities. The maximum counts of swans and each species of geese could be combined because there were no unidentified birds. Thus, dabbling duck and Canada goose concentrations reached a peak near the end of August through early September; diving duck and white-fronted goose densities were greatest in mid-September; and snow goose and swan densities were greatest in mid-October. Although no Ross' geese were recorded, it is believed they were present in the Delta. Some flocks may have been misidentified as snow geese. Previously, Ross' geese were recorded in the Delta between mid-September and mid-October (Soper, 1951:47).

Although density estimates have been obtained (Table 10), it is believed (as was the case for spring-staging birds) that it is more practicable to determine minimum habitat requirements for potential fall populations. Again, following the analysis used for spring staging ducks, it was evident that mud flat, immature fen, and emergent edge were preferred habitats of dabblers; emergent areas of restricted-drainage lakes and open, deep streams were preferred by divers; and emergents and open-drainage immature fen and mud flat were preferred by geese and swans. To some extent transient waterfowl utilize whatever

Table 10. Fall-staging waterfowl densities based on sample counts, Peace-Athabasca Delta, 1971.[1]

Habitat Type	Drainage	DUCKS Dabblers	Divers	Dabblers Per Mile	Divers Per Acre
Emergent	Restricted	2184 (21.1)[2]	1319 (6736)	103.5	0.20
	Open	50113 (77.3)	- (0)	648.3	-
Open water lakes	Restricted		822 (26365)		0.03
	Open		2038 (51862)		0.04
Open water rivers	Open		72 (548)		0.13
Mud flat	Restricted	24191 (25.8)		937.6	
	Open	27694 (33.0)		1142.2	
Immature fen	Restricted	21841 (40.9)		534.0	
	Open	23634		230.1	
Meadow	Restricted	5216 (28.9)		180.5	
	Open	- (0)		-	
Low shrub	Restricted	739 (10.1)		73.2	
	Open	2790 (26.5)		105.3	
Tall shrub	Restricted	- (0)		-	
	Open	33 (18.6)		1.8	

(Continued on next page.)

Table 10. Continued.

Habitat Type	Drain-age	GEESE Canada	W.F.	Snow	Swans	Geese & Swans Per Mile
Emergent	R	0 (21.1)	390 (28.5)	0 (16.7)	880 (16.7)	66.4
	O	2720 (77.3)	20 (75.2)	5491 (121.1)	2968 (121.1)	105.3
Mud flat	R	320 (25.8)	0 (26.3)	0 (55.1)	0 (55.1)	12.4
	O	705 (33.0)	0 (77.1)	1000 (101.5)	2257 (101.5)	53.5
Immature fen	R	1603 (40.9)	0 (43.0)	- (0)	- (0)	39.2
	O	526 (102.7)	55 (80.3)	2367 (80.3)	3216 (80.3)	75.3
Meadow	R	0 (28.9)	0 (18.9)	- (0)	- (0)	0.0
	O	- (0)	- (0)	- (0)	- (0)	-
Low shrub	R	513 (10.1)	- (0)	- (0)	-	50.8
	O	804 (26.5)	0 (3.3)	0 (3.3)	0 (3.3)	30.3
Tall shrub	R	- (0)	- (0)	- (0)	- (0)	-
	O	143 (18.6)	0 (18.6)	- (0)	- (0)	7.7

[1] Dabbler and Canada goose census: late Aug.-early Sept.; diver and white-fronted goose census: mid-Sept.; snow goose and swan census: mid-October.

[2] Numbers in parentheses are sample sizes: in miles for dabblers, geese and swans; in acres for divers. While the routes remained virtually the same between counts, edge type amounts changed due to fluctuating water levels.

habitat is available, particularly on the larger lakes, thereby obscuring evidence of habitat preferences. We cannot be sure to what extent waterfowl would concentrate in other habitats if the aforementioned were limited or absent; but, as was mentioned earlier, availability of "dryland" edge is a limiting factor. The preference by dabblers, geese, and swans for emergent, mud flat, and immature fen shoreline on large lakes was very evident in 1971. If floodwaters were high, eliminating such edge, fewer birds would utilize the Delta as a stopover. The effect that this might have on the success of their southward migration is unknown, but the implications are certainly obvious.

Estimates of breeding-pair, production, and potential molting populations for the Delta in 1971 were 162,700, 610,800, and 500,000, respectively. This means that at least 1,110,800 (610,800 + 500,000) ducks would have used the Delta as a staging area before northern migrants arrived. If we assume that the mid-October waterfowl census included only transient birds from further north, and that we counted 50 percent to 75 percent of all such birds present in the Delta (both feasible assumptions), then 79,300 to 122,000 ducks and 35,900 to 55,300 geese and swans could be added to the preceding figure, to yield a total estimate of 1,190,000 to 1,232,800 ducks plus 35,900 to 55,300 geese. These are rough estimates, and it is felt that both the duck-production and molting-population estimates may be high. The greatest number of geese and swans seen in a single census was 27,630. If we assume that we counted 50 percent to 75 percent of the population, and that a turnover of such numbers

occurred twice, then the total fall population estimates ranged from 110,200 to 165,800. These estimates are noteworthy in consideration of the fact that the spring-staging estimate was 145,000. For all species, except whistling swans, the sample counts revealed considerably greater numbers in the spring than in the fall. This would seem to indicate that many fall migrants may use an alternative route or that we have underestimated the amount of turnover. Densities as high as 4,900 dabblers per mile, 700 geese per mile, and 80 swans per mile were recorded for specific census areas (Appendix 5). Although such densities would never be realized throughout the entire Delta, it appears that many more fall-staging waterfowl could have been accommodated under the 1971 habitat conditions. But what are the minimum habitat requirements? If 800,000 to 850,000 dabblers were to use the Delta concurrently as a fall staging area (derived from foregoing estimates), and if such birds can concentrate in densities of up to 4,900 per mile (open-drainage mud flat), then at least 160 to 175 miles of such habitat would be required. Again we may be overlooking the complexity of the requirements, as was discussed for molters. In the case of divers, if 385,000 were to use the Delta concurrently, and if such birds can concentrate in densities of 1.32 per acre (open water of restricted-drainage lakes; see Appendix 5), then 284,000 acres of such habitat would be required. This figure probably reflects the effect of large sample units; that is, divers on specific sites concentrate in considerably greater densities, and actual habitat requirements could be much less.

OVERVIEW OF AN OPTIMUM WATER LEVEL REGIME TO ACCOMMODATE ALL SEGMENTS OF THE WATERFOWL POPULATION

The foregoing sections have been an attempt to evaluate minimum and optimum habitat requirements for the four waterfowl population segments. To meet these requirements on a long-term basis, a specific annual water regime is required. The significance of different requirements for restricted- vs open-drainage systems here becomes apparent.

The production period, May 1 to July 31, is of utmost importance; water management plans should center on this period. It has been recommended that a complete variety of edge types be distributed throughout the Delta in order to accommodate breeding pairs and nesting of all waterfowl species. However, emphasis should be placed on the more productive edge types.

The most important habitat types, in order of significance according to waterfowl densities, were computed for each of the population segments of dabblers, divers, geese, and swans (Table 11). Also described was what was believed to be the water level regime necessary to provide such conditions within a given year (Fig. 4). These are implied optimum conditions and not necessarily those which would maximize utilization of a particular habitat type: not all types can be maximized simultaneously.

There are two periods during which water sources are significantly available: first, local runoff occurring at spring breakup; and second, when mountain snowmelt reaches the Delta

Table 11. Preferred habitat types, according to waterfowl densities, of various population segments; and water regimes necessary to promote optimum habitat conditions.

Population Segment and Time Period	Most Preferred Habitat Types, in Order of Significance			Implied Optimum Water Level Regime
	Dabblers	Divers	Geese/Swans	
Spring staging: Breakup to May 15-20	Mud flat-R Meadow-O Imm. fen-R Emergent-O Imm. fen-O Mud flat-O	Emergent-R Tall shrub-R Meadow-R Low shrub-R Rock-R Deciduous-R	Mud flat-O Imm. fen-O Imm. fen-R Mud flat-R Low shrub-R Meadow-R	Water levels at or somewhat above those of the preceeding fall - Levels of perched basins as well as open drainage systems slightly below spill level, leaving areas of marginal emergents as well as narrow margins of mud flat and immature fen.
Breeding pairs: May 1-June 30	Meadow-O Meadow-R Emergent-O Emergent-R Tall shrub-R Low shrub-R/ Imm. fen-R	Tall shrub-R Emergent-R Low shrub-R Deciduous-R Coniferous Meadow-R		Water levels raised enough to flood perched basins every 3 to 5 years (+?). In interim years, water levels raised to full level of first stage of basins. This means that the water levels in basins of the remaining stages will depend on the balance between local spring runoff and evaporation.
Production: May 1-July 31	Meadow-O Meadow-R Tall shrub-R/ Imm. fen-R Imm. fen-O Mud flat-R	Tall shrub-R Deciduous-R Emergent-R Coniferous-R Low shrub-R Meadow-R		Water levels prescribed for breeding pairs maintained or slightly lowered. Minor increases on open drainage systems would not be detrimental. During years of flooding to recharge perched

(Continued on next page.)

Table 11. Continued.

Population Segment and Time Period	Most Preferred Habitat Types, in Order of Significance			Implied Optimum Water Level Regime
	Dabblers	Divers	Geese/Swans	
				basins, water levels should be lowered as soon as possible after flooding to promote the edge types preferred by breeding pairs, and thereafter maintained or lowered slightly through to the end of July.
Molters: June 15-Aug. 15	Marginal emergents-O Open water-R Open water-O Emergents-R Marginal emergents-R	Open water-O Marginal emergents-O/ Open water-R Emergents-R Marginal emergents-R		Water levels at or slightly below those of the preceding period.
Fall staging: Aug. 15-Oct. 25	Mud flat-O Mud flat-R Emergent-O Imm. fen-R Imm. fen-O Meadow-R	Emergent-R Open rivers-O Open lakes-O Open lakes-R	Emergent-O Imm. fen-O Emergent-R Mud flat-O Low shrub-R Imm. fen-R	Water levels slightly lower than the preceding period. This would probably be achieved by natural processes of seepage and evapotranspiration.

through the Peace and Athabasca Rivers (late June through early July). Perched basins, which are so important to production, cannot be filled without raising water levels to such an extent and at such a time that considerable duck production would be lost. Production may be maximized, however, by raising the water level every three to five years to a level which would recharge all perched basins. This would serve several purposes:

(1) It would allow for fall drawdowns to promote growth of emergents.

(2) The periodic flooding would inhibit too extensive and too dense a growth of such emergents, and also the advance of other successional growth stages.

(3) It would maintain the early-successional-stage nature of restricted drainage basins.

(4) It would provide for a maximum of shoreline habitat of all types while fulfilling the foregoing functions.

(5) It would reduce the potential for nest loss by flooding to once in three to five years.

The major prerequisites for achieving the suggested optimum regime include:

(1) Insurance that the early spring runoff would be adequate to achieve the desired levels in years between prescribed floods.

(2) Insurance that water sources would be adequate to achieve

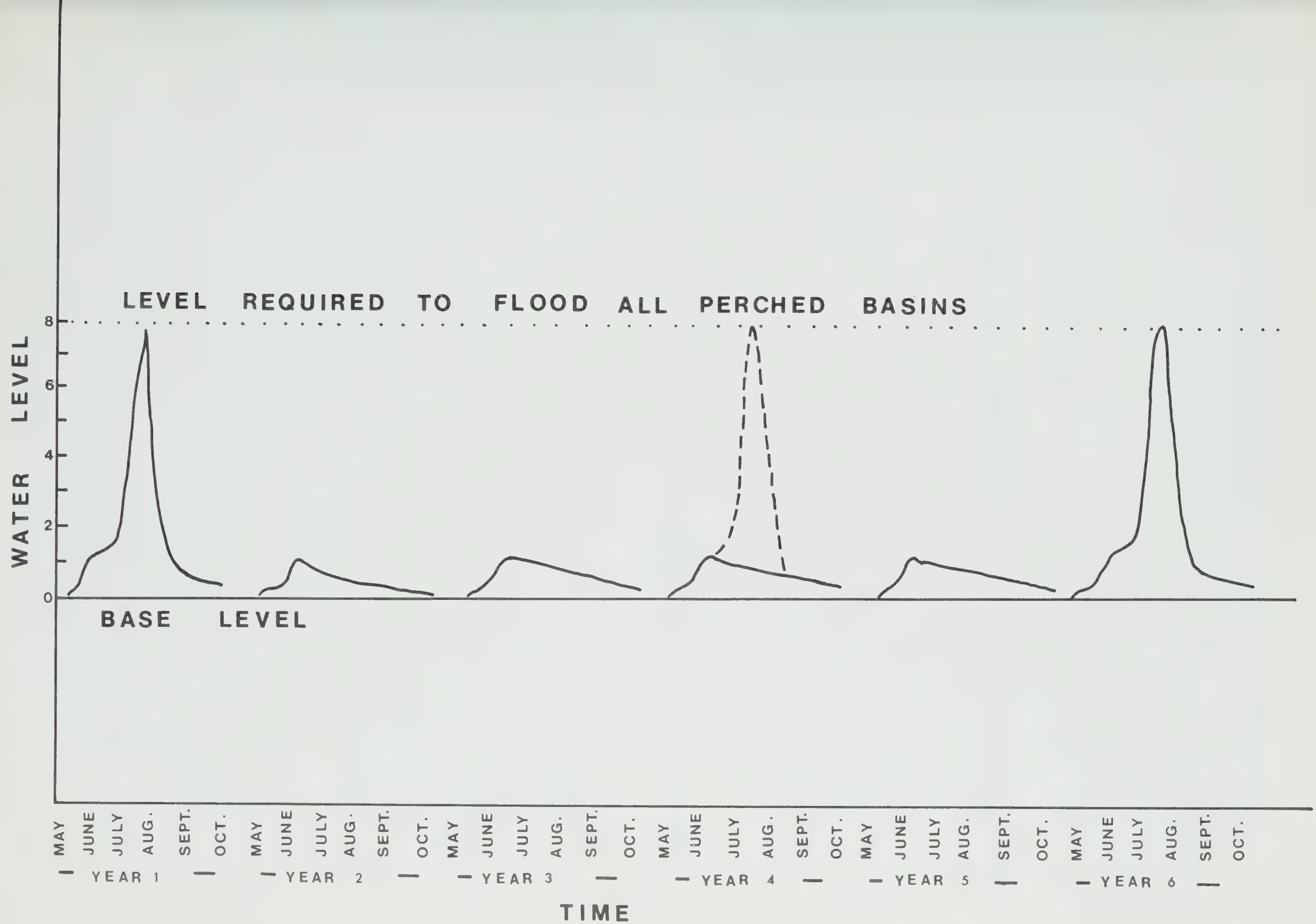


Fig. 4 Water regime indicated as necessary to promote optimum habitat conditions for waterfowl in the Peace - Athabasca Delta.

the desired flood levels once in three to five years.

(3) Insurance that such floodwaters can be removed immediately to promote at least some nesting and renesting in the same season, and to promote conditions suitable for molting and fall staging populations.

(4) Prevention of excessive flooding in years between prescribed floods, thus ensuring optimum nesting success.

The normal flood period occurs during the first half of July, but may begin by late June. This presents a threat to a large proportion of waterfowl nests (26 percent of the dabblers and 56 percent of the divers not hatched by June 30, 1971).

APPLICATION OF CONCLUSIONS TO SPECIFIC PORTIONS OF THE DELTA

In deriving waterfowl density estimates, we found the means of samples taken from all parts of the Delta. These means have been used to extrapolate population estimates for the entire Delta or for individual compartments. This was the most practicable method available although sample sizes of each habitat type were not equal for all compartments. In fact, sample sizes within compartments were not large enough to permit detection of differences if they existed. It is apparent, however, that the mean densities did not apply equally to all parts of the Delta. For example, meadow shoreline along lakes adjacent to the southeast side of Lake Claire supports greater densities of ducks than such edge in compartment G. Therefore, in evaluating the potential waterfowl use of any particular compartment or

group of compartments (for purposes of management, etc.), one should consider, at least subjectively, the attractiveness of those areas relative to the mean density. Some measure of the relative potential for waterfowl utilization (per shoreline mile or wetland acre) of the 10 compartments (treating I-J as one) might be made by assigning ratings, giving the value of one to the compartment with the greatest potential (Table 12). Thus, in promoting production through water management measures, one would be well advised to look first at compartment G, then the Claire-Mamawi complex, and then the Chipewyan Reserve. One would find, however, that compartment G has relatively secure water level conditions, and therefore, that first efforts should be directed to compartments I-J, H and F (Fig. 1).

EXISTING AND POTENTIAL IMPROVEMENT MEASURES

The rock weir (with spill level at 688 a.s.l.), which was constructed at Quatre Fourches in November, 1971, can be expected to provide for the recharge of many isolated and restricted drainage basins in compartment I-J. It is suggested that a level of 686 to 688 be considered a base level for this area, upon which to base future water level management (Fig. 4).

1971 was an unusual year in that the simultaneous high discharge of the Athabasca and Peace Rivers produced a substantial flood on the Delta in spite of the constraints on the Peace. Such a phenomenon cannot be expected to recur often or predictably. Even at that, a large proportion of restricted drainage basins were not recharged, particularly in I-J. If it is found that

Table 12. Estimated relative waterfowl-utilization values of the ten compartments of the Peace-Athabasca Delta.

Compartment	Population Segment			
	Spring-staging	Breeding & Production	Molting	Fall-staging
A	4	7	5	5
B	7	6	4	6
C	6	6	3	3
D	3	7	3	2
E	2	5	2	2
F	8	3	4	7
G	5	1	2	4
H	7	2	5	8
I-J	1	2	1	1
K	7	4	4	9

floodwaters in the future fail to provide sufficient water to recharge the perched basins at least once in five years, secondary construction on individual restricted-drainage basins is recommended. Considerable potential for such works exists on basins adjacent to Lakes Claire and Mamawi. Potential for wetland improvement on an individual (tertiary) and block (secondary) basis is evident in other areas of the Delta. Several basins in the Chipewyan Reserve have a low productive capacity because their waters drain into Lake Athabasca following the spring thaw, and they are not recharged by moderate summer floods. With controlled water levels, development of aquatic vegetation, including excellent emergent cover, would be rapid. Reticulated low levees would provide good nesting habitat. Lake 85 is an example of such a basin (Fig.1). A large proportion of the basins on the Chipewyan Reserve could be suitably managed - both for muskrats and waterfowl - by construction of a dyke extending from the Fletcher Channel to the Goose Island Channel, just south of Flower Bay. Alternatively, these basins might be managed on an individual basis. Limon Lake and adjacent basins are another area of potential improvement as a unit. Compartment C, south of Canoe Portage, including Grey Wavy Lake, lends itself to improvement by dyking. Basins adjacent to, and draining into, Riviere des Rochers could be tremendously improved with small weirs.

If and when it becomes feasible to intensify management procedures within the Delta, and depending on the effects of water-management developments, the opportunities will likely

exist to employ such techniques as internal ditching, pothole blasting, and construction of nesting islands. In particular, efforts should be made to promote nesting of Canada geese.

Although more will have been said of this in the hydrologists' report, several alternatives exist for primary management of the water in the Delta and Lake Athabasca. Plans for secondary or tertiary developments await decisions on these alternatives.

An ice dam on the Riviere des Rochers--the potentiality of which was investigated during the winter of 1971-72--could, to some extent, provide the desirable water regime outlined previously (Fig. 4). Of course, several facets of such an operation remain to be examined in greater depth.

LOCAL SIGNIFICANCE OF DELTA WATERFOWL

The magnitude of direct, local consumptive use of waterfowl in the Delta is virtually impossible to measure. In general terms, however, it is obvious that waterfowl form a substantial part of the diet of many Delta residents, being eaten fresh in spring and summer and frozen for use in winter. Although meat can be purchased at the Hudson's Bay store, waterfowl (as well as other wild game) provide relatively inexpensive variety and thus supplement the income.

Many duck eggs were once taken for food and were considered to have a significant effect in depressing production. This practice has probably been discontinued for three (or more) reasons:

(1) concentration of people in Fort Chipewyan making excursions for egg collecting economically unjustified.

(2) the difficulty in locating duck nests, and

(3) the availability of alternative foods, including "store-bought" eggs.

An insignificant amount of egg collecting probably occurs incidental to other activities, especially by people living or camping in the Delta away from Fort Chipewyan.

Treaty Indians and natives with registered traplines do not require a licence to hunt waterfowl in season. Therefore, there is no record and no indication of numbers of birds taken by these groups. In 1971, 53 natives and 18 non-native people purchased bird licenses through the Department of Lands and Forests at Fort Chipewyan. Of the non-natives hunting in the Delta area, most are people temporarily residing there, such as government personnel, and some are passing through on business and hunt coincidentally. In other words, there are few, if any, outsiders who travel to Fort Chipewyan specifically to hunt waterfowl. Construction of an all-season road to Fort Chipewyan would undoubtedly change this situation. With this in view, there is future economic potential for Fort Chipewyan through hunting-associated services including guiding, equipment, food, and accommodation. Hopefully, such gains would accrue directly to the native people rather than to outside investors. These same services would apply as well to activities other than hunting (which is restricted to the non-Park Delta and to a

short period of the year), such as scientific studies, fishing, photography, natural history education, camping, and general tourism.

Pending decisions regarding management of wetland habitat, the Delta will offer employment opportunities to natives in construction of water-control and habitat-improvement works, and in on-going programs of water management.

NATIONAL AND INTERNATIONAL SIGNIFICANCE OF DELTA WATERFOWL

> "These passages (fall migration routes) obey topographic features such as lakes, marshes, and rivers when these lead toward wintering grounds, overland routes being followed when there is no direct watercourse." (Hochbaum 1955:110)

A glance at a map of the water courses of western Canada will reveal the prime location of the Peace-Athabasca Delta with respect to waterfowl movement. The edge of the Shield on the east, the Rocky Mountains on the west, and the general direction of the Mackenzie River system usher the biannual migrations of many waterfowl through the Delta. The Delta serves as a funneling point for movements of birds which breed along the Arctic coast. These transients, plus the Delta residents, in moving south to wintering grounds, spread east and west across much of the continent. The main direction of movement, however, as indicated by recoveries of birds banded in the Delta, is through the Central and Mississippi Flyways (Table 13).

Table 13. Distribution of recoveries of waterfowl banded in the Peace-Athabasca Delta.

Recovery Location	Mallard	Black	Gadwall	Widgeon	G.W.Teal	B.W.Teal	Shov-eler	Pintail
Total Recoveries	1104	1	5	24	74	13	5	423
CANADA	250(23)*	0(0)	2(40)	5(21)	5(7)	1(8)	1(20)	80(19)
British Columbia								3
Alberta	99		1	2	1		1	39
Saskatchewan	137		1	1	2			34
Manitoba	13			1	1	1		2
Ontario	1			1				1
Mackenzie					1			
Quebec								1
PACIFIC FLYWAY	35(3)	0(0)	0(0)	4(17)	12(16)	0(0)	2(40)	95(22)
Washington	8							4
Idaho	21							4
Oregon	2			1				7
California	2			2	6		1	70
Nevada				1	2			2
Utah	2				2		1	7
Arizona					2			1
CENTRAL FLYWAY	392(36)	0(0)	2(40)	5(21)	28(38)	6(46)	2(40)	123(29)
Montana	33			1				1
Wyoming	10							
North Dakota	64				3			9
South Dakota	45				1	2		8
Nebraska	79				6		1	14
Colorado	38				3			2
Kansas	38		1	1	4	2		18
Oklahoma	26				2	1		3
New Mexico	2							3
Texas	57		1	3	9	1	1	65

(Continued on next page.)

Table 13. Continued.

Recovery Location	Redhead	Canvasback	L. Scaup	Bufflehead	Canada Goose	Total Ducks & Geese
Total Recoveries	27	16	30	5	17	1744
CANADA	2(7)	1(6)	3(10)	1(20)	9(53)	360(21)
British Columbia		1				4
Alberta	1				9	153
Saskatchewan	1					176
Manitoba			1	1		20
Ontario			2			5
Mackenzie						1
Quebec						1
PACIFIC FLYWAY	5(19)	5(31)	0(0)	0(0)	0(0)	158(9)
Washington						12
Idaho		1				26
Oregon	1					11
California	4	4				89
Nevada						5
Utah						12
Arizona						3
CENTRAL FLYWAY	9(33)	5(31)	3(10)	0(0)	8(47)	583(33)
Montana	1					36
Wyoming						10
North Dakota	1	1				78
South Dakota		2				58
Nebraska					7	107
Colorado	1		1			45
Kansas	1					65
Oklahoma						32
New Mexico	1					6
Texas	4	2	2		1	146

(Continued on next page.)

Table 13. Continued.

Recovery Location	Mallard	Black	Gadwall	Widgeon	G.W.Teal	B.W.Teal	Shov-eler	Pintail
MISSISSIPPI FLYWAY	420(38)	1(100)	1(20)	4(17)	26(35)	3(23)	0(0)	96(23)
Minnesota	23			2	5	2		7
Iowa	47				1			6
Wisconsin	8				1			4
Illinois	43				3			5
Missouri	57				3			6
Arkansas	105				1			2
Louisiana	79			2	12			64
Mississippi	23	1						1
Alabama	2							
Tennessee	19		1					
Kentucky	2							
Indiana	6							1
Ohio								
Michigan	6					1		
ATLANTIC FLYWAY	7(1)	0(0)	0(0)	3(13)	0(0)	0(0)	0(0)	2(0.5)
Delaware				1				
Maryland	2			1				
Virginia				1				
South Carolina	3							
Georgia	2							
Florida								2

(Continued on next page.)

Table 13. Continued.

Recovery Location	Redhead	Canvasback	L. Scaup	Bufflehead	Canada Goose	Total Ducks & Geese
MISSISSIPPI FLYWAY	9(33)	3(19)	14(47)	3(60)	0(0)	580(33)
Minnesota	1	1	6	1		48
Iowa			2			56
Wisconsin	2	1	1	2		19
Illinois	1					52
Missouri						66
Arkansas						108
Louisiana	1		2			160
Mississippi			1			26
Alabama	1		1			4
Tennessee						20
Kentucky						2
Indiana			1			8
Ohio						
Michigan	3	1				11
ATLANTIC FLYWAY	2(7)	1(6)	8(27)	1(20)	0(0)	24(1)
Maine			1			1
Pennsylvania			1	1		2
Delaware						1
Maryland	2	1	2			8
Virginia						1
South Carolina						3
Georgia			1			3
Florida			3			5

(Continued on next page.)

Table 13. Continued.

Recovery Location	Mallard	Black	Gadwall	Widgeon	G.W.Teal	B.W.Teal	Shov-eler	Pintail
MEXICO				2(8)	3(4)	1(8)		25(6)
Bahama Islands				1(4)				
Panama						1(8)		
Venezuela						1(8)		
Nicaragua								
Guatemala								1(0.2)
Oceania								1(0.2)

(Continued on next page.)

Table 13. Continued.

Recovery Location	Redhead	Canvasback	L. Scaup	Bufflehead	Canada Goose	Total Ducks & Geese
MEXICO		1(6)				32(2)
Bahama Islands						1(0.1)
Panama			1(3)			2(0.1)
Venezuela						1(0.1)
Nicaragua			1(3)			1(0.1)
Guatemala						1(0.1)
Oceania						1(0.1)

* Numbers in parentheses are percentages.

As mentioned by Soper (1951), the Delta is, as well, probably the most important northern river delta in terms of waterfowl production, providing both a complex variety of habitat types suitable for nesting, and a frost-free season long enough to allow for a high success of first nest attempts plus successful renesting. With protection from early summer floods, potential exists for increased hatching success. Although such floods occurred in 1971, much of the Delta was unaffected and much of the hatching was completed before floodwaters peaked; therefore, success was high.

One of the very important functions of the Delta in terms of the continental waterfowl resource is to serve as a "retreat" in years of drought (Smith et al., 1964:51-52). When such drought occurs, flocks of non-breeding pairs may reside on northern marshes; in years when conditions on the prairies improve, waterfowl are known to have a great capacity to recover in numbers.

Although the phenomenon is difficult to assess, it is likely that as wetland conditions throughout the prairies have deteriorated over the years, a greater proportion of the waterfowl population has moved further north to breed. In view of drainage activities and alternative demands for water in the south, conservationists have recognized, as well, the growing necessity of preserving and improving northern wetlands for waterfowl. The Peace-Athabasca Delta, like other northern river deltas such as the Saskatchewan, Mackenzie, and Yukon, is a key waterfowl area in terms of existing contributions to waterfowl

numbers, potential for intensified management, and potential for contributing knowledge towards the nature, significance, and management of such deltas. Also, the more northern marshes will have increasing recreational value as accessibility improves and as the demand increases for more "natural" environments (wilderness) away from urban areas. The assets include: the economic value of imminent tourism and hunting, the aesthetic value to both local people and visitors, and the scientific value as a unique area of study of a wide variety of wildlife, fish, and plant communities. These assets extend far beyond the Delta boundaries: the value of all migratory species is increasing and will continue to increase throughout the continent.

We can only speculate as to the exact effects that loss or continued serious alteration of the Delta would have on populations of migratory birds. Certainly there would be a substantial loss of recruitment--in the neighborhood of one half million ducks annually. There would also be an alteration of midsummer movements of molting ducks. But what of transient spring and fall populations? Swans, for example, are present in the Delta from breakup, in late April or early May, until the end of May, and from late August until freeze-up in late October. If the Delta were suddenly eliminated (i.e., over a period of a few years), or if it no longer provided the habitat types required, what effect would this have on the migratory and reproductive success of these birds? Hopefully, we will never learn the answers through experience.

There is an obligation on the part of all Canadians to maintain the aesthetic unit of the Delta, in which waterfowl form part of its complex natural community, and which is of indeterminate value to the psychological well-being of all those who are, or who will become, aware of its existence.

SUMMARY - 1971

1. The complex system of various wetland habitat types in the Delta makes it ideally suited to the needs of staging, molting, and breeding waterfowl.

2. Prior to construction of the Bennett Dam, occasional summer floods maintained the early-successional-stage community types over much of the Delta, revitalizing it with a wide variety of wildlife species. However, such flooding also reduced waterfowl production by flooding out nests. On the other hand, a series of years of low water would reduce the amount of available shoreline and nesting habitat. Therefore, although the Delta almost always provided good staging habitat in spring and fall, production was highly variable.

Since 1968, the floods required to recharge perched basins have not occurred,and the amount of available shoreline and nesting habitat has been progressively reduced. Meanwhile, nesting success has probably been greater than in the past. There comes a point, however, when increased success rates do not compensate for lost nesting habitat. At such a time it becomes necessary, from a management viewpoint, to re-establish the wetlands at the expense of a temporary decrease in production.

3. Phenologically, the 1971 season progressed as follows: breakup - April 20; peak spring-staging populations - first week of May; nest initiation - April 15 to June 20 (peak - May 15 to June 7); hatching - May 15 to July 31 (peak- June 15 to July 8); molting - June 1 to August 15; fall staging - August 15 to

October 24.

4. Water bodies in the Delta can be classified according to water-level relationships, as isolated, restricted (both of these have been referred to as "restricted" in this report), and open. The average rate of water loss from 13 isolated basins in the Delta was 0.07 ft per week, between May 26 and October 24.

5. Mean densities of spring-staging ducks on various shoreline types ranged from zero to 225 per mile. Preferred shoreline types were immature fen and emergent. Delta population estimates were 432,500 ducks and 145,000 geese and swans. Lakes Claire, Mamawi, Athabasca, Baril, 236, Welstead, 66, 18, 94, and channel 399 were major concentration areas.

6. Breeding-pair densities ranged from 0.2 to 18.4 per mile for dabblers and 0.0 to 8.7 per mile for divers. Preferred edge types were meadow, emergent, tall shrub, and low shrub. There were an estimated 162,700 breeding pairs of ducks in the Delta.

7. Production-density estimates ranged from 0.0 to 55.2 per mile, the greatest densities occurring on meadow, tall shrub, and emergent shorelines. Total production was estimated at 610,800.

8. Molting-duck density estimates ranged from zero to 30 per acre. Marginal emergents and central portions of open lakes were preferred by dabblers and divers respectively. A rough estimate of the molting duck population was 500,000. Notable concentration areas included lakes along the southeast side of

Lake Claire (301, 304, 305), portions of the north end of Lake Claire (402), the Birch River Delta (345), lake 239, and much of Mamawi Lake.

9. Fall-staging density estimates ranged from two to 1142 per mile for dabblers, 0.03 to 0.20 per acre for divers, and zero to 105 per mile for geese and swans. Preferred shoreline types were mud flat, emergent, and immature fen. The fall population was estimated at approximately 1,200,000 ducks and 110,200 to 165,800 geese and swans. Main concentration areas were the same as for molters, but included Welstead Lake and the south shore of Lake Athabasca.

10. The optimum water-level regime, as indicated by the requirements of the four segments of the waterfowl population, would be one which provides for recharging of all perched basins every three to five years and which in interim years is maintained with only minor fluctuations about a base level. This regime is designed to maximize, on a long-term basis, the amount of available waterfowl habitat and waterfowl production. Uncertainties in establishment of such a regime include timing and magnitude of floods and the potential for their control.

11. Depending on primary water-management measures, potential exists for secondary and tertiary control measures on groups of lakes or single lakes, with considerable improvement in production capacity being visualized.

12. Numerous species of birds, mammals, and fish in the Delta bear direct and indirect ecological relationships to waterfowl.

Any water management plans shall take all species into account in an effort to maintain a diverse, balanced community of organisms of sustained aesthetic, scientific, and economic value.

13. The waterfowl, which migrate through and breed within the Delta, are a past, present, and potential future asset to the economic and aesthetic well-being of Fort Chipewyans, Canadians, and North Americans in general. The task of re-establishing and improving the dynamic, productive character of the Peace-Athabasca Delta is a North American responsibility.

ADDENDUM - 1972 INVESTIGATIONS

Between May and October of 1971, a series of waterfowl surveys was conducted as part of an ecological assessment of the Peace-Athabasca Delta. In April, 1972, a report of the findings on waterfowl was submitted to the Project Task Force, to be incorporated into a comprehensive report on the Delta. The water levels in the Delta in 1971 were low relative to the mean of the decade preceding the construction of the Bennett Dam. The waterfowl populations reflected the corresponding habitat conditions.

In 1972 a large proportion of the Delta was reflooded through a fortuitous combination of water discharges in the Peace, Athabasca, and Birch Rivers. Waterfowl surveys were repeated to evaluate the effects of the habitat changes. This report provides the results of those surveys.

METHODS

For the most part, the 1972 waterfowl surveys followed the same routes as those conducted in 1971. However, the number of surveys was reduced: from five to two spring surveys (staging and breeding birds), from four to three brood surveys, and from five fall surveys to one. Molting-duck surveys were omitted in 1972.

The water gauges established in 1971 were checked at one-to-two week intervals between May 3 or 16 and July 28, 1972.

GENERAL ECOLOGICAL AND PHENOLOGICAL OBSERVATIONS

WATERFOWL

Breakup occurred a week to 10 days later in 1972 than in 1971; however, the phenological waterfowl pattern did not appear to differ significantly. The first aerial reconnaissance was made May 1. At that time mallards, pintails, shovelers, widgeon, green-winged teal, canvasback, goldeneye, bufflehead, snow geese, Canada geese, and swans were present in the Delta. Franklin's gulls, ring-billed gulls, killdeer, and other shorebirds, and bald eagles had also returned.

Most transient waterfowl had departed from the Delta by late May. The nest-initiation period of observed resident ducks ranged from mid-April to mid-June. Fifty-nine percent of observed successful dabbler broods and 37 percent of diver broods were hatched by June 30. Corresponding figures for 1971 were 74 percent and 44 percent respectively. By July 15, 1971, these percentages had increased to 98 and 95 respectively. Brood data for mallards, shovelers, canvasbacks, goldeneye, redheads, and buffleheads revealed two nest-initiation peaks, but samples were small in some cases.

As only one fall count was made in 1972, interpretations of the phenological pattern must be based on the period of observations, September 1-14. Residents of Fort Chipewyan reported, and our observations tended to substantiate the fact, that many of the resident waterfowl of the Delta had departed before September 1. During the period of observation, then, the

population gradually increased from that low level to a level estimated to be one-half to two-thirds of the expected transient population for that autumn.

WATER LEVELS

Several water level records, based on staff gauges established in 1971, were incomplete due to the relatively high water levels throughout the Delta in 1972 (overtopping the gauges). Levels in restricted- and open-drainage basins peaked briefly at mid-May and notably around July 7, the point of inflection occurring June 15 to 20.

HABITAT

The relatively high water levels of 1972 produced some very significant changes in amounts of the various shoreline or edge types. Our census routes were more or less the same in 1971 and 1972; however, whereas we surveyed waterfowl on 192 miles of open-drainage mud flat in the spring of 1971, there were only four miles of such habitat on the same route in 1972. Similarly, the amount of open-drainage immature fen changed from 114 to four miles. On the other hand, the amount of censused open-drainage meadow and emergent edges increased from 14 to 295 miles and 15 to 52 miles respectively (Table 14).

According to preliminary computer calculations (Townsend, pers. comm.), there was a 60 percent reduction in shoreline available in perched basins on May 1, 1972 as compared to May 1, 1971 (a 44 percent reduction in total shoreline miles). These figures

Table 14. Spring-staging duck densities, Peace-Athabasca Delta, 1971-72.[1]

Habitat Type	Drainage	Miles Sampled 1971	Miles Sampled 1972	Dabblers: Mean Density 1971	Dabblers: Mean Density 1972	Divers: Mean Density 1971	Divers: Mean Density 1972
Emergent	Restricted	96.00	112.06	5.8	0.9	13.3	16.0
	Open	15.25	51.95	68.5	64.7	1.0	6.4
Mud flat	Restricted	13.10	-	92.1	-	0	-
	Open	192.05	4.20	59.0	11.0	1.1	9.3
Immature fen	Restricted	109.92	24.10	76.2	5.7	0.2	0
	Open	113.70	4.30	64.8	0	1.4	0
Meadow	Restricted	105.73	140.52	19.7	15.1	6.8	8.0
	Open	13.91	294.97	83.5	65.3	0.6	23.3
Low shrub	Restricted	11.47	78.65	13.9	0.3	6.0	38.2
	Open	48.10	83.10	6.8	4.0	0	12.3
Tall shrub	Restricted	17.19	59.40	5.5	0	7.4	9.1
	Open	22.14	16.11	2.9	0	1.1	0
Deciduous	Restricted	1.88	0.40	(2.5)[2]	(1.5)	(1.0)	(1.5)
	Open	-	3.76	(3.0)	(1.5)	(4.0)	(6.0)
Coniferous	Restricted	-	-	(2.0)	(1.0)	(2.5)	(3.5)
	Open	-	-	(1.5)	(0.8)	(1.0)	(1.5)
Rock	Restricted	1.70	1.87	(0)	(0)	(5.0)	(7.0)
	Open	-	-	(0)	(0)	(1.0)	(1.5)

[1]1971--May 4-9; 1972--May 10-20.

[2]Bracketed figures are estimates based on densities of other edge types.

are based on May 1 water levels of 684.5 ft and 689.7 ft a.s.l. in 1971 and 1972 respectively.

RESULTS AND DISCUSSION

SPRING STAGING

It would be hazardous to make direct extrapolations of Delta populations from our sample counts; however, a comparison of density estimates for 1971 and 1972 shows quite clearly that numbers of staging dabbling ducks declined while divers increased (Table 14). While other factors such as continental populations, vagaries of weather patterns, and distribution of birds within the Delta may have had some influence, it was obvious that altered habitat conditions reflecting higher water levels had contributed to these density phenomena.

In the 1971 report it was stated that:

> "the edge types preferred by dabblers were mud flat, meadow, immature fen, and emergent; the types preferred by divers were emergent, tall shrub, meadow, and low shrub. ...The data do not tell us, however, to what extent the waterfowl would concentrate on other shoreline types if the aforementioned were absent or limited."

The 1972 data provide at least some clarification on this point. Proportionately, meadow and open-drainage emergent edge types received greater utilization by dabblers as amounts of mud flat and immature fen were reduced. Some of these apparent

preferences are not so much a manifestation of the edge type as of the area through which the ducks traditionally migrate. Factors such as offshore water depth and food availability may be determinant. Thus, a section of immature fen shoreline may have attracted numerous dabbling ducks in 1971. Due to higher water levels, this same section may have been classified as meadow in 1972. Although it appears that the overall waterfowl densities on the Delta were lower in 1972, a preference was again exhibited for the shallow water (with its probable good food supply) along that section of shoreline. In the analysis it may appear that the birds were redistributed within the Delta, but this was not necessarily the case. These considerations also apply (perhaps most significantly) to geese and swans (Table 15). Divers exhibited similar utilization patterns in both years.

BREEDING WATERFOWL

The reductions in breeding-pair densities for dabblers in 1972 relative to 1971 were not as pronounced as the indicated declines in staging-bird numbers. The average decrease for all edge types was 36 percent, ranging from 6 percent to 56 percent. There was no evident pattern of redistribution of pairs; however, with the exception of mud flat (small sample), low shrub, and tall shrub, reductions were greater for open-drainage systems than restricted-drainage systems (Table 16).

Changes in densities of breeding divers ranged from -63 percent to +200 percent, with an average of +12 percent. However, the

Table 15. Numbers of spring-staging geese and swans counted in the Peace-Athabasca Delta, 1971-72.

		Miles Sampled		Numbers of Geese		Numbers of Swans	
Habitat Type	Drainage	1971	1972	1971[1]	1972[2]	1971	1972
Emergent	Restricted	80.33- 92.55	112.06	4	41	0	196
	Open	17.95	51.95	0	6,675	27	1,019
Mud flat	Restricted	13.1	-	979	-	67	-
	Open	185.45-198.85	4.20	35,592	10	3,777	0
Immature fen	Restricted	99.22	24.10	5,695	6,000	8	0
	Open	223.90-235.50	4.30	29,735	0	3,526	0
Meadow	Restricted	103.33-122.44	140.52	1,177	135	0	91
	Open	12.81	294.97	0	17,577	0	4,801
Low shrub	Restricted	13.07	78.65	800	0	100	0
	Open	43.10- 48.10	83.10	3	2,650	4	353
Tall shrub	Restricted	13.99- 17.19	59.40	0	15	0	0
	Open	37.44	16.11	0	0	0	0
Deciduous	Restricted	-	0.40	-	0	-	50
	Open	1.88	3.76	0	0	0	0
Coniferous	Restricted	0- 1.30	-	0	-	0	-
	Open	-	-	-	-	-	-
Rock	Restricted	4.02-3.20-4.40	1.87	0	0	0	79
	Open	-	-	-	-	-	-
Totals		850-916	875	73,985	33,103	7,509	6,589

[1]Data based on three counts.
[2]Data based on one count.

Table 16. Waterfowl breeding-pair densities, Peace-Athabasca Delta, 1971-72.

Habitat Type	Drainage	Miles Sampled 1971	Miles Sampled 1972	Dabbler Pair Density 1971	Dabbler Pair Density 1972	Diver Pair Density 1971	Diver Pair Density 1972
Emergent	Restricted	80.33- 92.55	112.06-122.34	13.5	9.9	6.1	5.9
	Open	17.95	51.95- 78.50	14.1	6.2	0.5	1.2
Mud flat	Restricted	13.10	-	8.3	(4.4)	0.2	0.2
	Open	185.45-198.85	4.20- 2.30	4.7	(2.8)	0.0	0.2
Immature fen	Restricted	99.22	24.10- 56.90	9.3	8.4	0.3	0.2
	Open	223.90-235.50	4.30- 37.50	8.5	4.6	0.1	0.3
Meadow	Restricted	103.33-122.44	140.52-103.42	16.3	11.6	3.8	3.0
	Open	12.81	294.97-132.40	18.4	9.5	1.6	0.8
Low shrub	Restricted	12.37- 13.07	78.65- 67.13	9.3	5.1	5.2	4.7
	Open	48.10	83.10- 59.80	5.6	4.4	0.3	0.4
Tall shrub	Restricted	17.19	59.40- 53.64	12.0	8.0	8.7	3.3
	Open	37.44	16.11- 58.91	6.9	6.5	1.9	0.7
Deciduous	Restricted	-	0.40	(5.6)*	(4.8)	4.4	(3.8)
	Open	1.88	3.76	2.9	(2.3)	0.0	(0.9)
Coniferous	Restricted	1.30	-	3.3	(2.1)	4.3	(2.7)
	Open	-	-	(1.1)	(0.5)	0.6	(1.1)
Rock	Restricted	3.20- 4.40	1.87- 2.42	0.9	(0.4)	1.0	(1.1)
	Open	-	-	(0.2)	(0.1)	0.0	(0.1)

*Bracketed figures are estimates based on densities of other edge types.

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bias of small samples (e.g., open-drainage immature fen) places the reliability of some of the figures in question. It is more probable, considering each of the density figures, that there was an overall decline in pair densities of divers as well as dabblers.

The question naturally arises, assuming the continental population remains reasonably constant, of where the breeding pairs go when the Delta habitat is not as attractive as it can be. When water conditions are good on the prairies, a larger-than-average proportion of the population can be stopped short of reaching the Delta. If conditions on the prairies in 1972 were unchanged from or drier than in 1971 (as in fact they were), the implication would be that the breeders moved further north or into areas between the prairies and the Delta. Preliminary reports of the surveys by the U. S. Bureau of Sport Fisheries and Wildlife (stratum 15) confirm our observations regarding both breeding pairs and production. Apparently, there was a pronounced increase in numbers of breeding pairs in stratum 14 which includes most of northern Alberta except the Delta and Slave River region. While the indices for breeding pairs of dabblers and divers increased throughout northern Alberta, northeastern British Columbia, Yukon, and the Northwest Territories, the production index for northern Alberta and the Northwest Territories was 50 percent below that of 1971.

PRODUCTION

Sample sizes were small or nil for several edge types in 1972. For those, estimates are provided (in parentheses, Table 17) relative to other edge types.

There were two (or more) reasons for the reduction in brood densities as shown in Table 17. The more significant would be the reduction in breeding-pair densities as previously discussed. The second was the possible reduced success rate of those ducks which did breed. Ratios of broods-to-pair densities for each edge type in 1971 and 1972 are shown in Table 18. The mean ratio for both dabblers and divers was reduced in 1972 indicating a lower success rate. The most probable explanation appears to be the gradually increasing water levels (flooding of nesting habitat) during the nesting period. As noted earlier, water levels generally began to rise June 15 to 20 and peaked around July 7.

FALL STAGING

No attempt was made to determine densities of fall-staging populations as was done in 1971. Rather, the results of the single census were interpreted relative to the five counts made in 1971 (Tables 19, 20).

There was considerable change in amounts of the various shoreline types censused between 1971 and 1972 (Tables 10,19). Emergents had developed along what were previously classified as meadow shorelines. Whereas 295 miles of open-drainage meadow

Table 17. Waterfowl brood densities, Peace-Athabasca Delta, 1971-72.

		Miles Sampled		Dabblers		Divers	
Habitat Type	Drainage	1971	1972	1971	1972	1971	1972
Emergent	Restricted	65.52	93.83	7.8	1.9	6.6	3.6
	Open	15.55	1.00	2.0	(0.4)	0.6	(0.3)
Mud flat	Restricted	-	-	(0.5)	(0.3)	(0)	(0)
	Open	2.05	-	0.0	(0)	0.0	(0)
Immature fen	Restricted	7.98	1.50	13.4	(0.3)	1.5	(0)
	Open	12.30	-	3.8	(0)	1.1	(0)
Meadow	Restricted	47.62	47.91	13.6	3.1	3.5	0.8
	Open	9.51	1.30	2.6	(1.0)	0.1	(0.3)
Low shrub	Restricted	1.90	5.80	0.0	1.0	5.8	1.5
	Open	5.00	8.60	0.0	0.1	2.0	0.6
Tall shrub	Restricted	14.62	22.48	4.6	2.5	7.7	4.6
	Open	37.44	10.81	0.4	0	0.2	0
Deciduous	Restricted	-	-	(4.0)*	(1.0)	(7.0)	(2.0)
	Open	-	9.06	(0.4)	0.1	(0.2)	0.1
Coniferous	Restricted	1.30	-	(4.6)	(0.8)	(6.2)	(1.5)
	Open	-	-	(0.2)	(0.3)	(0.1)	(0.5)
Rock	Restricted	-	-	(0.0)	(0)	(0.0)	(0)
	Open	-	-	(0.0)	(0)	(0.0)	(0)

*Bracketed figures are estimates based on densities of other edge types.

Table 18. Ratios of brood-to-pair densities, dabblers and divers, Peace-Athabasca Delta, 1971-72.

Habitat Type	Drainage	Dabblers 1971	Dabblers 1972	Divers 1971	Divers 1972
Emergent	Restricted	0.6	0.2	1.1	0.6
	Open	0.1	0.1	1.2	0.3
Mud flat	Restricted	0.1	0.1	0.0	0.0
	Open	0.0	0.0	0.0	0.0
Immature fen	Restricted	1.4	0.0	5.0	0.0
	Open	0.4	0.0	11.0	0.0
Meadow	Restricted	0.8	0.3	0.9	0.3
	Open	0.1	0.1	0.1	0.4
Low shrub	Restricted	0.0	0.2	1.1	0.3
	Open	0.0	0.0	6.7	1.5
Tall shrub	Restricted	0.4	0.3	0.9	1.4
	Open	0.1	0.0	0.1	0.0
Deciduous	Restricted	0.7	0.2	1.6	0.5
	Open	0.1	0.0	-	0.1
Coniferous	Restricted	1.4	0.4	1.4	0.6
	Open	0.2	0.6	0.2	0.5
Rock	Restricted	0.0	0.0	0.0	0.0
	Open	0.0	0.0	0.0	0.0

Table 19. Fall-staging waterfowl census summary, Peace-Athabasca Delta, 1972.

Habitat/Dr.		Miles Sampled	Dabblers	Divers	Uniden-tified	Adjusted Dabblers	Adjusted Divers	Shoreline for Geese & Swans	Geese	Swans
Emergent	-R	179.7	13,990	3565	16,410	27,118	6,847	177.8	2,445	2
	-O	233.0	14,465	2886	5,367	18,940	3,781	242.3	3,364	1,015
Mud flat	-R	None censused for ducks				-	-	9.6	1,060	45
	-O	33.6	7,029	929	154	7,165	947	36.6	3,345	206
Imm. fen	-R	None censused				-	-	-	-	-
	-O	4.8	3	0	0	3	0	12.4	5,104	
Meadow	-R	1.9	22	0	72	94	0	11.4	821	3,564
	-O	4.3	40	5	71	103	13	29.3	705	6
Low shrub	-R	1.6	11	0	0	11	0	1.6	4	4
	-O	None censused				-	-	-	-	-
Tall shrub	-R	7.0	31	0	12	43	0	7.0	12	0
	-O	35.2	73	168	52	89	204	35.2	13	0
Totals		501.1	35,664	7553	22,138	53,566	11,792	563.2	16,873	4,842

Table 20. Waterfowl fall-staging census summary, Peace-Athabasca Delta, 1971-72.

Census Period	Sample Size	Dabblers	Divers	Geese	Swans
Shorelines:					
1971					
Aug.9-19	384.6	106,945	669	434	0
Aug.30-Sept.4	384.6	169,335	3,985	7,340	8
Sept.16-18	374.8	135,706	4,772	6,174	718
Sept.30-Oct.3	374.8	132,626	3,621	6,346	3,852
Oct.12-14	305.2	60,840	116	16,149	11,481
1972					
Sept.6-14	501.1	53,566	11,792	16,873*	4,842*

* Shoreline for geese and swans = 563.2 miles.

shoreline had been surveyed in the spring, only 4.3 miles of such habitat were surveyed in the fall. Again, it was not so much a matter of edge-type preference as location-preference (with previously mentioned inferences) that revealed 73 percent of the sampled waterfowl population on emergent shoreline.

Following the pattern of spring-staging and breeding-pair populations, fall-staging dabbling ducks decreased in 1972. Our single census, while covering a greater total mileage than any of the 1971 surveys, revealed 12 percent fewer dabblers than the lowest of the 1971 counts. Meanwhile, divers increased by 147 percent over the highest 1971 count (note, however, that there were 115 more miles of shoreline counted in 1972). While it was not felt that we counted the peak populations of all species of geese, the single census revealed 4 percent more geese than the highest 1971 count (again, however, note the larger shoreline sample). Also, the impression was that the swans were counted before they reached their maximum population.

Interpretation of the dabbler decline involves four (or more) possible factors: (1) a relatively low northern population, (2) less attractive staging habitat, (3) timing of the fall census relative to migratory movements, and (4) lack of a pronounced post-breeding movement toward the Delta by waterfowl south of and lateral to the Delta.

The relative numbers of dabblers and geese may be at least partially explained by timing of the survey and by habitat conditions. Also, some sections of the north shore of Lake

Claire were surveyed for geese but not for ducks. Forty-five hundred snow geese were counted on one such section. Note that 60 additional miles of shoreline were surveyed for geese and swans only.

SUMMARY - 1972

Although there were increases in some instances, the general effect of the higher water levels of 1972 relative to 1971 was to depress waterfowl utilization of the Peace-Athabasca Delta. The reductions (or increases) may be attributed to one or a combination of the following factors:

1. A reduction in total available dry land edge, but especially a reduction of edge associated with perched basins.

2. A significant alteration of relative amounts of the various edge types due to higher water levels and vegetational development since 1971. The juxtaposition of food plants, emergent cover, and suitable dry land edge was notably altered as well.

3. Timing of the surveys relative to waterfowl migrations.

4. Distribution of migratory and breeding waterfowl.

5. Changes in numbers of waterfowl, of the various species, available for the northward migration in all flyways.

6. The effect of early summer flooding on waterfowl nesting success.

7. Relative availability of suitable waterfowl habitat elsewhere: on the prairies, in the parklands, and in boreal areas south of, and lateral to, the Delta.

While the relatively high Delta water level was at least partially instrumental in reducing waterfowl utilization, it did serve to recharge a large proportion of the perched basins, thus retarding hydrarch succession and providing for additional land-water edge for the next few years, if similar floods do not recur.

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APPENDICES

Appendix 1. Scientific names of animals mentioned in this report.

Common Name (and Abbreviation)	Scientific Name
Birds	
Red-necked (Holboell's) grebe	*Podiceps grisegena*
Horned grebe	*Podiceps auritus*
Pied-billed grebe	*Podilymbus podiceps*
Great blue heron	*Ardea herodias*
American bittern	*Botaurus lentiginosus*
Whistling swan	*Olor columbianus*
Trumpeter swan	*Olor buccinator*
Canada goose	*Branta canadensis*
White-fronted goose (W.F.)	*Anser albifrons*
Snow goose	*Chen caerulescens*
Ross' goose	*Chen rossii*
Mallard (Mal)	*Anas platyrhynchos*
Black duck	*Anas rubripes*
Gadwall (Gad)	*Anas strepera*
Pintail (Pin)	*Anas acuta*
Green-winged teal (GWT)	*Anas carolinensis*
Blue-winged teal (BWT)	*Anas discors*
American widgeon (Wid)	*Mareca americana*
Shoveler (Sho)	*Spatula clypeata*
Redhead (Red)	*Aythya americana*
Ring-necked duck (Ring)	*Aythya collaris*
Canvasback (Can)	*Aythya valisineria*
Greater scaup	*Aythya marila*
Lesser scaup (LScp,Scp)	*Aythya affinis*
Common goldeneye (GEye)	*Bucephala clangula*
Bufflehead (Buff)	*Bucephala albeola*
Ruddy duck (Rud)	*Oxyura jamaicensis*
White-winged scoter	*Melanitta deglandi*
Surf scoter	*Melanitta perspicillata*
Red-tailed hawk	*Buteo jamaicensis*
Golden eagle	*Aquila chrysaetos*
Bald eagle	*Haliaeetus leucocephalus*
Marsh hawk	*Circus cyaneus*
Osprey	*Pandion haliaetus*
Peregrine falcon	*Falco peregrinus*
Sparrow hawk (kestrel)	*Falco sparverius*

(Continued on next page.)

Appendix 1. Continued.

Common Name (and Abbreviation)	Scientific Name
Sora rail	*Porzana carolina*
American coot	*Fulica americana*
Killdeer	*Charadrius vociferus*
Spotted sandpiper	*Actitis macularia*
Greater yellowlegs	*Totanus melanoleucus*
Lesser yellowlegs	*Totanus flavipes*
California gull	*Larus californicus*
Ring-billed gull	*Larus delawarensis*
Black tern	*Chlidonias niger*
Snowy owl	*Nyctea scandiaca*
Belted kingfisher	*Megaceryle alcyon*
Common raven	*Corvus corax*
Common crow	*Corvus brachyrhynchos*
American robin	*Turdus migratorius*
Pine grosbeak	*Pinicola enucleator*
Snow bunting	*Plectrophenax nivalis*
Mammals	
River otter	*Lutra canadensis*
Shorttail weasel	*Mustela erminea*
Mink	*Mustela vison*
Skunk	*Mephitis mephitis*
Red fox	*Vulpes fulva*
Coyote	*Canis latrans*
Gray wolf	*Canis lupus*
Muskrat	*Ondatra zibethica*
Beaver	*Castor canadensis*
Moose	*Alces alces*
Bison	*Bison bison*
Fish	
Goldeye	*Hiodon alosoides*
Northern pike	*Esox lucius*
Pickerel (walleye)	*Stizostedion vitreum*

Appendix 2. Adjustments of indicated pair densities of ducks.

A. Breeding pair correction factors (percent).

Habitat Type	Vehicle[1]	Observ-ability	Turn-over	Non-Breeding	Selection Bias	Unident. Pairs	Total
Dabblers							
Emergent	H	+15	+10	- 5	-15	+ 4	+ 9
	A	+15	+10	- 5	-		+27
Mud flat	H	-	+ 5	-20	-	+ 4	-11
	A	-	+ 5	-20	-	+ 7	- 8
Meadow	H	+ 5	+10	-	-15	+ 4	+ 4
	A	+ 5	+10	-	-	+ 7	+22
Low shrub	H	+10	+ 5	- 5	- 5	+ 4	+ 9
	A	+10	+ 5	- 5	-	+ 7	+17
Tall shrub	H	+ 5	-	-	-	+ 4	+ 9
	A	+ 5	-	-	-	+ 7	+12
Deciduous	H	+ 5	-	-	-	+ 4	+ 9
	A	+ 5	-	-	-	+ 7	+12
Coniferous	H	-	-	-	-	+ 4	+ 4
	A	-	-	-	-	+ 7	+ 7
Rock	H	-	-	-	-	+ 4	-80[2]
	A	-	-	-	-	+ 7	-80
Immature fen	H	-	+ 5	-10	-	+ 4	- 1
	A	-	+ 5	-10	-	+ 7	+ 2

(Continued on next page.)

Appendix 2.A. Concluded.

Habitat Type	Vehicle[1]	Observ-ability	Turn-over	Non-Breeding	Selection Bias	Unident. Pairs	Total
Divers							
Emergent	H	+12	+ 5	- 8	-10	+ 3	0
	A	+12	+ 5	- 8	-	+ 6	+15
Mud flat	H	-	-	-15	-	+ 3	-12
	A	-	-	-15	-	+ 6	- 9
Meadow	H	+ 5	+ 5	- 8	-10	+ 3	- 5
	A	+ 5	+ 5	- 8	-	+ 6	+ 8
Low shrub	H	+10	+ 5	- 5	-	+ 3	+13
	A	+10	+ 5	- 5	-	+ 6	+16
Tall shrub	H	+ 5	+ 3	- 3	-	+ 3	+ 8
	A	+ 5	+ 3	- 3	-	+ 6	+11
Deciduous	H	+ 5	+ 3	- 3	-	+ 3	+ 8
	A	+ 5	+ 3	- 3	-	+ 6	+11
Coniferous	H	+ 5	-	-	-	+ 3	+ 8
	A	+ 5	-	-	-	+ 6	+11
Rock	H	-	-	-	-	+ 3	-80
	A	-	-	-	-	+ 6	-80
Immature fen	H	-	-	- 5	-	+ 3	- 2
	A	-	-	- 5	-	+ 6	+ 1

[1]H = helicopter; A = airplane

[2]Based on small sample size and on the fact that ducks seen on rock shorelines were probably there because of proximity of some other shoreline type.

Appendix 2. Continued.

B. Calculation of adjusted pair densities.

Habitat Type	a. Observed Indicated Pairs/Mile: Restricted & Open Drainage	b. 1/3 of Indicated Pairs/Mile (Helicopter)[1]	c. Correction Factor For Helicopter	d. (b) x (c)	e. 2/3 of Indicated Pairs/Mile (Airplane)	f. Correction Factor For Airplane
Dabblers						
Emergent	22.7	7.57	1.09	8.36	15.14	1.27
Mud flat	14.3	4.77	0.89	4.25	9.54	0.92
Meadow	29.8	9.96	1.04	10.36	19.92	1.22
Low shrub	13.0	4.33	1.09	4.72	8.67	1.17
Tall shrub	17.0	5.67	1.09	6.18	11.34	1.12
Deciduous	7.6	2.53	1.09	2.76	5.07	1.12
Coniferous	4.1	1.37	1.04	1.42	2.74	1.07
Rock	5.0	1.67	0.02	0.33	3.34	0.02
Immature fen	17.6	5.87	0.99	5.91	11.74	1.02
Divers						
Emergent	8.7	2.90	0.00	0.00	5.80	1.15
Mud flat	0.2	0.07	0.88	0.06	0.13	0.91
Meadow	5.2	1.73	0.95	1.64	3.47	1.08
Low shrub	4.8	1.60	1.13	1.81	3.20	1.16
Tall shrub	9.6	3.20	1.08	3.46	6.40	1.11
Deciduous	4.0	1.33	1.08	1.44	2.67	1.11
Coniferous	4.4	1.47	1.08	1.59	2.94	1.11
Rock	5.2	1.73	0.20	0.37	3.47	0.20
Immature fen	0.4	0.13	0.98	0.13	0.27	1.01

(Continued on next page.)

Appendix 2.B. Continued.

	g. (e) x (f)	h. (d) + (g)	i. (h) / (a)	Observed Indicated Pairs/Mile: Restricted Drainage	Observed Indicated Pairs/Mile: Open Drainage	Corrected Ind. Pairs/ Mile:Restr. Drainage (i) x (i)	Corrected Ind. Pairs/ Mile: Open Drainage (i) x (k)
<u>Dabblers</u>							
Emergent	19.23	27.59	1.214	11.1	11.6	13.5	14.1
Mud flat	8.78	13.03	0.911	9.1	5.2	8.3	4.7
Meadow	24.30	34.66	1.163	14.0	15.8	16.3	18.4
Low shrub	10.14	14.86	1.143	8.1	4.9	9.3	5.6
Tall shrub	12.70	18.88	1.110	10.8	6.2	12.0	6.9
Deciduous	5.68	8.44	1.110	5.0	2.6	5.6	2.9
Coniferous	2.93	4.35	1.060	3.1	1.0	3.3	1.1
Rock	0.67	1.00	0.200	4.4	1.0	0.9	0.2
Immature fen	11.97	17.88	1.015	9.2	8.4	9.3	8.5
<u>Divers</u>							
Emergent	6.67	6.67	0.766	8.0	0.7	6.1	0.5
Mud flat	0.12	0.18	0.900	0.2	0.0	0.2	0.0
Meadow	3.75	5.39	1.036	3.7	1.5	3.8	1.6
Low shrub	3.71	5.52	1.150	4.5	0.3	5.2	0.3
Tall shrub	7.10	10.56	1.100	7.9	1.7	8.7	1.9
Deciduous	2.96	4.40	1.100	4.0	0.0	4.4	0.0
Coniferous	3.26	4.85	1.102	3.9	0.5	4.3	0.6
Rock	0.69	1.06	0.203	5.0	0.2	1.0	0.0
Immature fen	0.27	0.40	1.000	0.3	0.1	0.3	0.1

[1]Helicopter counts provided approximately 1/3 of pairs, while airplane counts provided 2/3.

Appendix 3. Brood observability adjustment factors.

Edge Type	Dabblers	Divers
Emergent	1.54	1.27
Mud flat	1.03	1.01
Meadow	1.33	1.16
Low shrub	1.19	1.09
Tall shrub	1.14	1.07
Deciduous	No Broods	
Coniferous	1.43	1.21
Rock	No Broods	
Immature fen	1.10	1.05

Appendix 4. Third sample count (July 24-27) of molting waterfowl in the Peace-Athabasca Delta, 1971.

Habitat Type	Census Unit	Sample Size (A.)	Total Dabblers	Total Divers	Dabblers Per Acre	Divers Per A.
Open water, restricted drainage systems	209	107.4	523	3	4.86	0.02
	305	71.0	2,155	-	30.35	0.00
	304	45.5	478	-	10.50	0.00
	301	382.2	815	8	15.21	0.02
	320	76.4	656	76	8.58	0.99
	66	81.9	92	-	1.12	0.00
	222	287.6	321	-	1.11	0.00
	123	153.0	50	52	0.32	0.33
	Hilda L.	396.8	334	-	0.84	0.00
Open water, open drainage systems	60	105.6	32	34	0.30	0.32
	255	37.3	56	4	1.50	0.10
	402	47.3	527	594	11.14	12.55
	344(33)	189.3	813	-	4.29	0.00
	344(32)	207.5	53	-	0.25	0.00
	344(31)	91.0	191	-	2.09	0.00
	345	132.7	2,947	-	22.41	0.00
	Richardson L.	120.1	37	39	0.30	0.32
Marginal emergents, restricted drainage systems	313	263.9	133	-	0.50	0.00
	94	169.0	181	-	1.07	0.00
	Baril L.	527.8	12	9	0.02	0.01
Marginal emergents, open drainage systems	S.E.Claire(2)	145.6	221	2	1.51	0.01
	7	283.0	335	39	1.18	0.13
	Mamawi (1)	294.8	4,581	40	15.53	0.13
	Mamawi (3)	502.3	7,957	9	15.84	0.01
	Mamawi (4)	240.2	242	-	1.00	0.00
Emergents, restricted drainage systems	8	93.6	230	-	2.45	0.00
	18	114.5	50	6	0.43	0.05
	239	38.1	405	-	10.62	0.00
	32	30.9	53	8	1.71	0.25
	90	77.4	7	-	0.09	0.00
	50	80.0	146		1.82	0.00
	Frezie L.	34.6	5	8	0.14	0.23

Appendix 5. Fall-staging waterfowl counts, Peace-Athabasca Delta, 1971.

A. Dabblers and Canada geese: late August-early September.

Habitat Type	Location	Sample Size (mi.)	Total Dabblers	Canada Geese	Dabblers Per Mile	Can. Geese Per Mile
Emergent-O	Athabasca (1)	32.8	26,029	448	794	14
	" (2)	1.5	1,625	1,075	1,083	717
	" (3)	15.8	3,835	37	243	2
	" (4)	2.8	1,151	400	411	143
	St. Claire (3)	11.6	16,529	505	1,425	44
	Richardson (2)	1.2	27	30	23	25
	60	11.6	917	225	79	19
	Totals & Means	77.3	50,113	2,720	648.3	35.2
Emergent-R	Baril (2)	0.7	454	-	649	-
	" (3)	6.6	21	-	3	-
	90	7.9	231	-	29	-
	209	5.9	1,478	-	251	-
	Totals & Means	21.1	2,184	-	103.5	-
Mud flat-O	E. Claire (10)	4.8	2,050	-	427	-
	S.E. Claire (4)	13.4	4,723	330	352	25
	345	6.5	31,900	375	4,907	58
	Richardson (1)	8.3	21	-	3	-
	Totals & Means	33.0	37,694	705	1,142.2	21.4
Mud flat-R	18 (1)	0.9	42	-	47	-
	336 (3)	1.4	164	-	117	-
	336 (4)	0.9	51	-	57	-
	Welstead (4)	3.3	6,900	-	2,091	-
	" (3)	2.8	3,700	-	1,321	-
	" (1)	14.0	9,181	320	656	23
	304	2.5	4,153	-	1,661	-
	Totals & Means	25.8	24,191	320	937.6	12.4
Immature fen-O	344 (31)	5.0	5,448	-	1,090	-
	344 (32)	11.4	348	23	31	2
	344 (33)	10.4	1,261	18	121	2
	E. Claire (11)	15.9	8,620		542	9

(Continued on next page.)

Appendix 5.A. Continued.

Habitat Type	Location	Sample Size (mi.)	Total Dabblers	Canada Geese	Dabblers Per Mile	Can. Geese Per Mile
Immature fen-O (continued)	Prairie R.	3.3	16	-	5	-
	Mamawi (3)	27.6	5,596	285	203	10
	" (4)	13.2	517	-	39	-
	W. Claire (5)	6.7	780	-	116	-
	" (6)	9.2	1,048	50	114	5
	Totals & Means	102.7	23,634	526	230.1	5.1
Immature fen-R	Baril (1)	2.0	137	-	69	-
	216	15.1	4,410	1,603	292	106
	Welstead (2)	1.4	200	-	143	-
	301 (1,3)	18.5	10,719	-	579	-
	305	3.9	6,375	-	1,635	-
	Totals & Means	40.9	21,841	1,603	534.0	39.2
Meadow-R	18 (2)	17.1	2,667	-	156	-
	336 (1)	4.0	1,236	-	309	-
	336 (2)	3.9	423	-	108	-
	336 (5)	1.4	400	-	286	-
	301 (2)	1.6	103	-	64	-
	301 (4)	0.9	387	-	430	-
	Totals & Means	28.9	5,216	-	180.5	-
Low shrub-O	Prairie R.	3.3	16	-	5	-
	Richardson (3)	23.2	2,774	804	120	35
	Totals & Means	26.5	2,790	804	105.3	30.3
Low shrub-R	Blanche L.	10.1	739	513	73	51
	Totals & Means	10.1	739	513	73.2	50.8
Tall shrub-O	Birch R.	15.3	20	143	1	9
	Mamawi Cr.	3.3	13	-	4	-
	Totals & Means	18.6	33	143	1.8	7.7

Appendix 5. Fall-staging waterfowl counts, Peace-Athabasca Delta, 1971.
B. White-fronted geese: mid-September.

Habitat Type	Location	Sample Size (mi.)	Total Geese	Geese Per Mile
Emergent-O	Mamawi (3)	27.6	20	0.7
	S.W.Claire (6)	9.2	-	-
	" (5)	6.7	-	-
	S.E.Claire (3)	11.6	-	-
	Athabasca (2)	1.5	-	-
	Athabasca (3,4)	18.6	-	-
	Totals & Mean	75.2	20	0.3
Emergent-R	Baril (2,3)	7.3	390	53
	209	5.9	-	-
	301 (1,3)	7.4	-	-
	90	7.9	-	-
	Totals & Mean	28.5	390	13.7
Mud flat-O	Athabasca (1)	32.8	-	-
	Richardson L.	32.7	-	-
	60	11.6	-	-
	Totals & Mean	77.1	-	-
Mud flat-R	18 (1)	0.9	-	-
	18 (2)	8.6	-	-
	336 (3,4,5)	3.7	-	-
	Welstead (1)	7.0	-	-
	" (3)	2.8	-	-
	" (4)	3.3	-	-
	Totals & Mean	26.3	-	-
Immature-O	344 (31,32,33)	26.8	-	-
	E. Claire (11)	15.9	20	1.3
	E. Claire (10)	4.8	-	-
	Prairie R.	3.3	-	-
	Mamawi (4)	13.2	35	2.7
	W. Claire (4)→345	6.5	-	-
	S.E. Claire (4)	13.4	-	-
	Totals & Mean	83.9	55	0.7
Immature fen-R	Baril (1)	2.0	-	-
	216	15.1	-	-
	305	3.9	-	-
	304	2.5	-	-
	301 (1)	11.1	-	-
	Welstead (1)	7.0	-	-
	" (2)	1.4	-	-
	Totals & Mean	43.0	-	-
Meadow-R	18 (2)	8.5	-	-
	336 (1,2)	7.9	-	-
	301 (2,4)	2.5	-	-
	Totals & Mean	18.9	-	-
Low shrub-O	Prairie R.	3.3	-	-
Tall shrub-O	Birch R.	15.3	-	-
	Mamawi Cr.	3.3	-	-
	Totals & Mean	18.6	-	-

Appendix 5. Fall-staging waterfowl counts, Peace-Athabasca Delta, 1971.

C. Divers: mid-September.

Habitat Type	Location	Sample Size (mi.)	Total Divers	Divers Per Acre
Emergent-R		6,736	1,319	0.20
Open water, open drainage lakes	Mamawi	29,069	183	0.01
	Richardson	15,488	21	0.001
	Bay 344	7,205	1,834	0.25
	Totals & Mean	51,862	2,038	0.04
Open water, open drainage rivers	Prairie	118	36	0.30
	Birch	371	1	0.002
	Mamawi Cr.	59	35	0.59
	Totals & Mean	548	72	0.13
Open water-R	Baril	16,954	135	0.01
	209	1,109	31	0.02
	216	3,130	-	0.00
	305	469	622	1.32
	304	227	-	0.00
	301	2,287	14	0.01
	Welstead	2,189	20	0.01
	Totals & Mean	26,365	822	0.03

Appendix 5. Fall-staging waterfowl counts, Peace-Athabasca Delta, 1971.
D. Snow geese and swans: mid-October.

Habitat Type	Location	Sample Size (mi.)	Total Snow G.	Total Swans	Snow G. Per Mile	Swans Per Mile
Emergent-O	Mamawi (1,5)	12.3	-	58	-	5
	Mamawi (2)	14.2	-	229	-	16
	Mamawi (3)	27.6	-	410	-	15
	N.E. Claire (11)	15.9	752	510	47	32
	N.E. Claire (6-9)	14.8	105	909	7	61
	N.E. Claire (1-5)	18.8	3,949	595	210	32
	S.E. Claire (1,2)	5.0	-	80	-	16
	S.E. Claire (3,4)	12.5	685	177	55	14
	Totals & Means	121.1	5,491	2,968	45.3	24.5
Emergent-R	Baril L.	16.7	-	880	-	53
Mud flat-O	Mamawi (1,5)	12.3	-	57	-	5
	" (4)	13.2	-	-	-	-
	N.E. Claire (10)	4.8	-	-	-	-
	" (12)	11.1	-	632	-	57
	267	5.0	-	-	-	-
	N.E. Claire (22-26)	29.1	1,000	867	34	30
	" (13-21)	26.0	-	701	-	27
	Totals & Means	101.5	1,000	2,257	9.9	22.2
Mud flat-R	263	3.0		-	-	-
	Welstead	21.5	-	-	-	-
	301	21.0	-	-	-	-
	304	1.8	-	-	-	-
	305	4.0	-	-	-	-
	Totals & Means	55.1	-	-	-	-
Immature fen-O	Prairie R.	3.2	-	-	-	-
	N.E. Claire (33)	10.4	-	706	-	68
	" (32)	11.4	-	153	-	13
	" (31)	5.0	100	76	20	15
	" (27-30)	11.6	160	918	14	79
	" (6-9)	6.3	1,317	198	209	31
	S.E. Claire (1,2)	5.1	-	79	-	15
	" (3,4)	12.5	685	177	55	14
	Totals & Means	80.3	2,367	3,216	29.5	40.0
Low shrub-O	Prairie R.	3.3	-	-	-	-

Appendix 5. Fall-staging waterfowl counts, Peace-Athabasca Delta, 1971.

E. Waterfowl counts, Old Fort Bay: Mud flat - 27.2 miles.

Census Date	Dabblers	Divers	Canada Geese	W. F. Geese	Snow Geese	Swans	Dabblers Per Mile	Geese & Swans Per Mile
October 6	15,007	38	700	-	-	1,845	551.7	93.6
October 12	8,307	39	992	-	-	2,160	305.4	115.9
October 19	9,820	-	1,175	-	-	1,862	361.0	111.7

SECTION L

STATUS OF THE MUSKRAT ON THE PEACE-ATHABASCA DELTA

by

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Lorraine Allison

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ABSTRACT

A study of population dynamics of the muskrat on the Peace-Athabasca Delta was conducted from March, 1971, to March, 1972, with emphasis on the effects of present low water conditions of the Delta.

Live-trapping and kill-trapping revealed that: the average number of muskrats per house was five; the average number of muskrats per bank run was three; the ratio of juveniles to adult females was 12.5:1; and the average litter size was six. Two litters were produced on most of the Delta lakes; however, three well-defined litters appeared in some areas.

Present muskrat numbers, as determined by aerial and ground survey, are low compared to previous years. The estimated population for fall, 1971, was 40,000 animals. Muskrat densities ranged from 0.1 to 11.4 muskrats per acre of emergent vegetation in subdivisions I and B respectively. The estimated breeding population for 1972 was 17,000 muskrats.

Low muskrat numbers on the Delta are attributed to low water levels. The most critical period is in winter when a shortage of water, restrictions of food accessibility, increased predation, and low temperatures place immediate stress on the muskrat population. Muskrat house activity, which is an indication of winter survival of the species, was dependent on the total depth of ice and water. There was a definite trend toward increased activity in houses as total depth increased. In 1971, 37 percent of all houses sampled were considered to be active compared to

55 percent in 1972. Critical minimum depths required for optimum muskrat survival were determined to be 2.5 feet in 1971 and 2.0 feet in 1972. At present, 70 percent of the Delta lakes do not fulfill these requirements. Approximately 45 percent of the muskrat population survived the winter of 1971-72. The shallower lakes were characterized by high mortality rates and numerous signs of predation.

Muskrats on South Egg Lake utilized all emergent plants; however, *Phragmites*, *Equisetum*, and *Typha* were given highest preference. Production varied from 1.5 muskrats per acre in *Scirpus* to 12.5 muskrats per acre in *Phragmites*. Muskrats built houses wherever emergents were present; therefore, water depth was of utmost importance.

The flooding of the Athabasca portion of the Delta in July, 1971, will benefit the muskrat population for the next two or three years. However, an increase in water depth will be necessary for effective muskrat management.

INTRODUCTION

The construction of the W.A.C. Bennett Dam in 1967 prompted a full-scale investigation of the Peace-Athabasca Delta to determine the ecological effects of changes in water regime.

The muskrat (Ondatra zibethicus spatulatus) is one of several mammalian species on the Delta which depends on an adequate water supply and a fluctuating water regime for breeding and year-round survival. Its prolific nature enables one to evaluate the short-term consequences of reduced water levels. Moreover, muskrat fur in the past has contributed significantly to the livelihood of local trappers. Muskrat trapping once constituted the basis of the fur economy for the entire Delta area (Fuller and La Roi, 1971).

Historically, the muskrat population on the Peace-Athabasca Delta has been a dynamic one, characterized by a postulated ten-year cycle of abundance (Fuller, 1951). This cyclic variation is probably due to a number of biological and climatological factors; however, evidence gathered thus far indicates that low water levels have played an important role in regulating muskrat numbers (Bellrose and Brown, 1941).

After spending two years on the Delta in the early 1930's, Soper (1942) stated that between 70,000 and 90,000 muskrat skins may be traded at Fort Chipewyan in a peak year; most of these were trapped on the Peace-Athabasca Delta. It is not known what percentage of the muskrat population is removed from the Delta by trappers; however, it is safe to assume that the population

at that time must have been well over 100,000.

Fuller (1951a) estimated a muskrat harvest of 40,000 - 50,000 animals in the Wood Buffalo Park portion of the Delta during the 1947-49 period. He mentioned: "At that time the population was recovering from a low in 1944-46 that coincided with low water levels. Willow and poplar seedlings were noted in 18 inches of standing water in one slough in the Delta that had presumably been dry during the low water years." (Fuller, 1951b; cited in Fuller and La Roi, 1971).

In the past, the periodic recurrence of high spring and summer water was responsible for recharging lakes and ponds and thus providing adequate habitat for muskrat breeding and winter survival. The hydrological regime was inconsistent from year to year. An occasional drawdown and subsequent replenishment by flooding ensured the production of a large area of marsh habitat.

A critical time for muskrats is the period between freeze-up and breakup (Fuller, 1951; Errington, 1963). While muskrats have little difficulty surviving drought conditions in the summer (Bellrose and Low, 1943), limitations of range, food, and water, due to winter freeze-outs, or partial freeze-outs, may pose a direct threat to the population. Consequently, water depths are of utmost importance in sustaining muskrats over winter.

Concurrent with the construction of the W.A.C. Bennett Dam and the filling of Williston Reservoir, water levels have been low in the last three years. The mean peak water level on Lake

Athabasca has been two to three feet lower than the long-term average (Dirschl, 1971). Consequently, a number of perched basins which once provided suitable habitat are now shallow or dry. Experienced local trappers maintain that many of these dry areas once produced muskrats.

In response to a growing concern for the altered Delta ecology, a study of population dynamics and related muskrat biology was conducted from March, 1971, to March, 1972. The main objectives were:

(1) to estimate the muskrat population on the Peace-Athabasca Delta;

(2) to determine the effect of changes in water level on muskrat populations;

(3) to estimate the percentage of the muskrat population which over-winters successfully;

(4) to determine a critical water depth for optimum muskrat survival;

(5) to determine relative productivity in different habitat types;

(6) to predict consequences of given water regimes on muskrat production; and

(7) to devise a water management plan that would maximize muskrat production.

DESCRIPTION OF STUDY AREA

Four regions were selected as study areas (Fig. 1). The bulk of the field work was confined to four lakes which were considered to be representative of study areas "A", "B", and "C". These were South Egg, North Egg, East Twin, and West Twin. Lakes in study area "D" were surveyed only for water depth.

South Egg Lake is located approximately 16 miles southeast of Fort Chipewyan on the southwest corner of the Chipewyan Reserve, in study area "A" (Fig. 2). During very high spring and summer flooding, the water level of the lake may be raised markedly by overflow of the Fletcher Channel, a branch of the Athabasca River. A small creek running southwest from Goose Island Channel and entering the lake at the northwest end also carries water in spring. The latter is more important under normal spring flooding conditions.

The lake itself covers approximately 1,700 acres, of which 615 acres are emergent vegetation; the rest is open water. In contrast to most Delta lakes, South Egg is relatively deep and hosts a variety of plant species.

Shoreline emergents are abundant, consisting mainly of cattail (_Typha latifolia_), horsetail (_Equisetum_ sp.), reed grass (_Phragmites communis_), bulrush (_Scirpus validus_ and _Scirpus_ sp.), bur reed (_Sparganium_ sp.), sweetflag (_Acorus_ sp.), sedge (_Carex_ sp.), and grass. Bog species such as smartweed (_Polygonum_ sp.) and cinquefoil (_Potentilla_ sp.) are also present.

FIG. 1 **Muskrat study areas on Peace-Athabasca Delta, 1971-72**

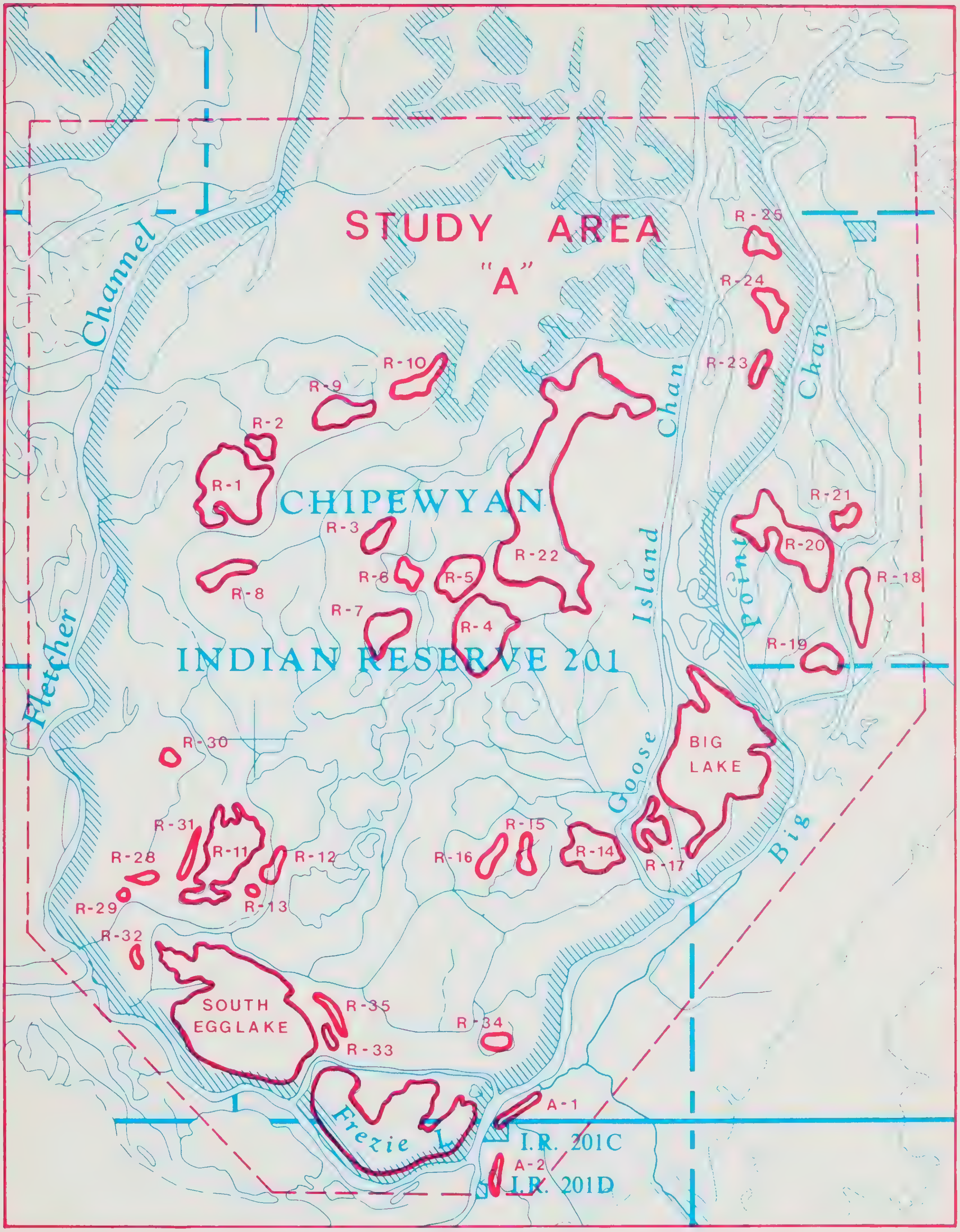

Fig. 2 Study area "A" showing lakes surveyed in fall and winter, 1971.

The shoreline is surrounded by willow (*Salix* sp.). Dense stands of emergent species occur between the shoreline and open water, except for 300 yards on the north end of the lake where willow and open water meet.

The dominant submergents are pondweed (*Potamogeton richardsonii* and *P. zosteriformis*) and water milfoil (*Myriophyllum* sp.). Duckweeds (*Lemna trisulca* and *L. minor*) are common, while arrowhead or duck potato (*Sagittaria* sp.) is confined to a small area in the east bay.

The emergent vegetation of South Egg Lake can be grouped into four distinct zones or habitat types (Fig. 3). The largest zone, having the most complex associations of plant species, is the mixed emergent stand (Fig. 3). It includes two or more of the above-mentioned shoreline emergents growing near one another. The mixed emergent stand extends as a broad band along the margins of the lake in the shallower portions of the littoral zone.

Several small stands of almost pure *Equisetum* constitute a second zone or habitat type (Fig. 3). Although *Equisetum* is abundant primarily in the mixed emergent stand and on raised portions of land adjacent to the lake, a few stands have become established separately near the old river channel. An occasional floating or rooted clump of *Sparganium*, *Typha*, or *Phragmites* may be interspersed with these otherwise homogeneous *Equisetum* stands.

The third zone consists of three dense stands of pure *Phragmites*

located offshore along the old river channel (Fig. 3). A few smaller *Phragmites* stands exist in association with other marsh species and are considered a part of the mixed emergent stand.

A fourth zone consists of two large stands of *Scirpus*, which cover the center of the lake on either side of the old river channel (Fig. 3).

North Egg Lake is located in Wood Buffalo National Park, approximately 11 miles northwest of Fort Chipewyan. It constitutes the entire region designated as study area "B" (Fig. 4). The water regime is relatively stable in contrast to South Egg Lake. North Egg lies along the west side of Revillon Coupe and receives water only during spring flooding when the Peace River spills over its banks.

The dominant emergent is *Carex* sp. which forms a large, extensive stand in the central and northern part of the lake. Shoreline emergents, mainly *Carex* and *Equisetum*, are abundant primarily on the west central and east shores, while the vegetation of the north and south shores is sparse and limited in distribution. *Acorus* and *Sparganium* are scattered in small patches throughout the central portions of the lake. *Typha* is relatively rare.

The Twin Lakes are located 16 miles southwest of Fort Chipewyan in study area "C" (Fig. 5). Like South Egg, both are supplied by the Athabasca drainage system and are directly affected by annual spring flooding.

Fig. 3 Distribution of emergent vegetation on South Egg Lake.

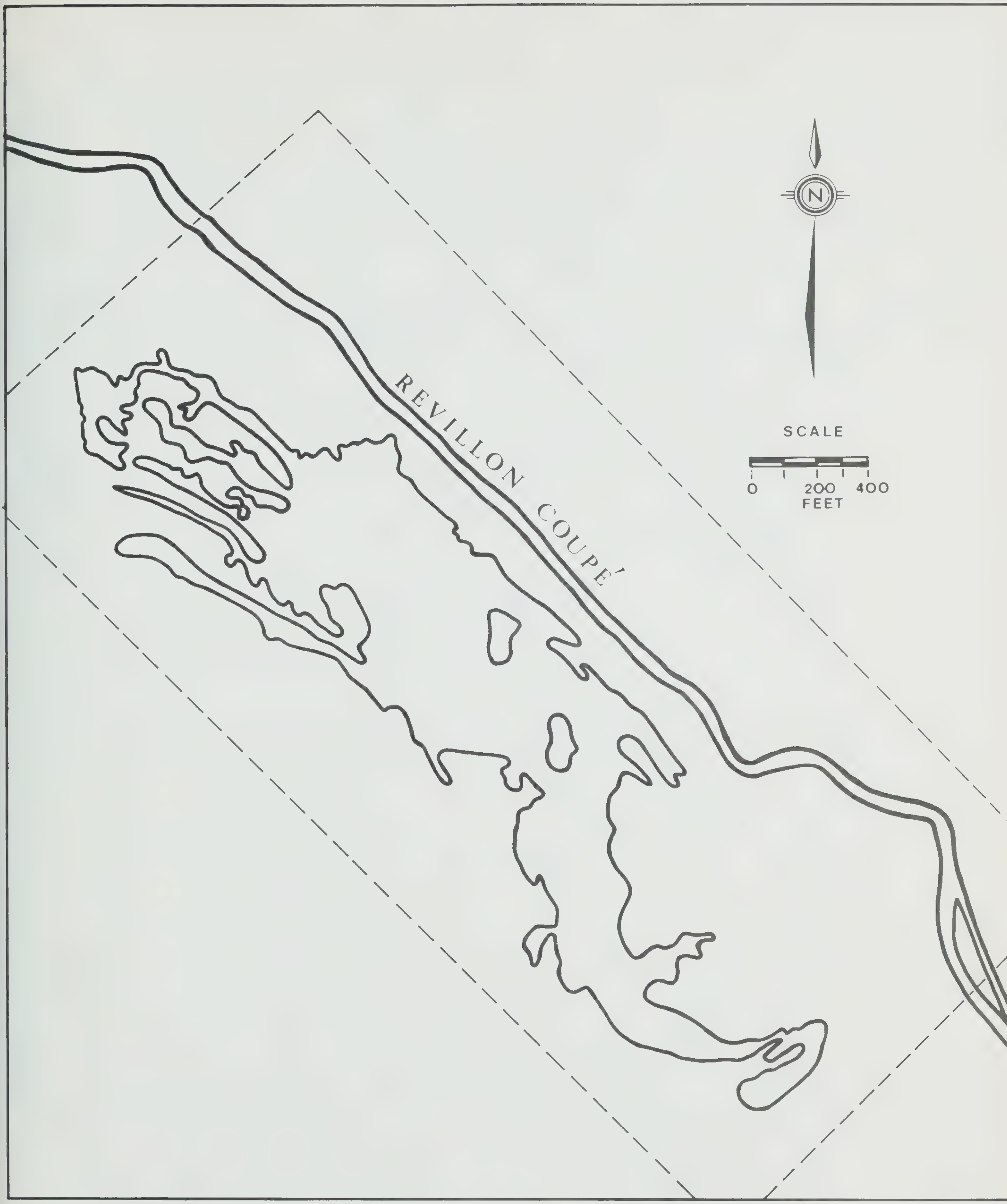

Fig. 4 Study area "B" showing lake surveyed in fall and winter, 1971.

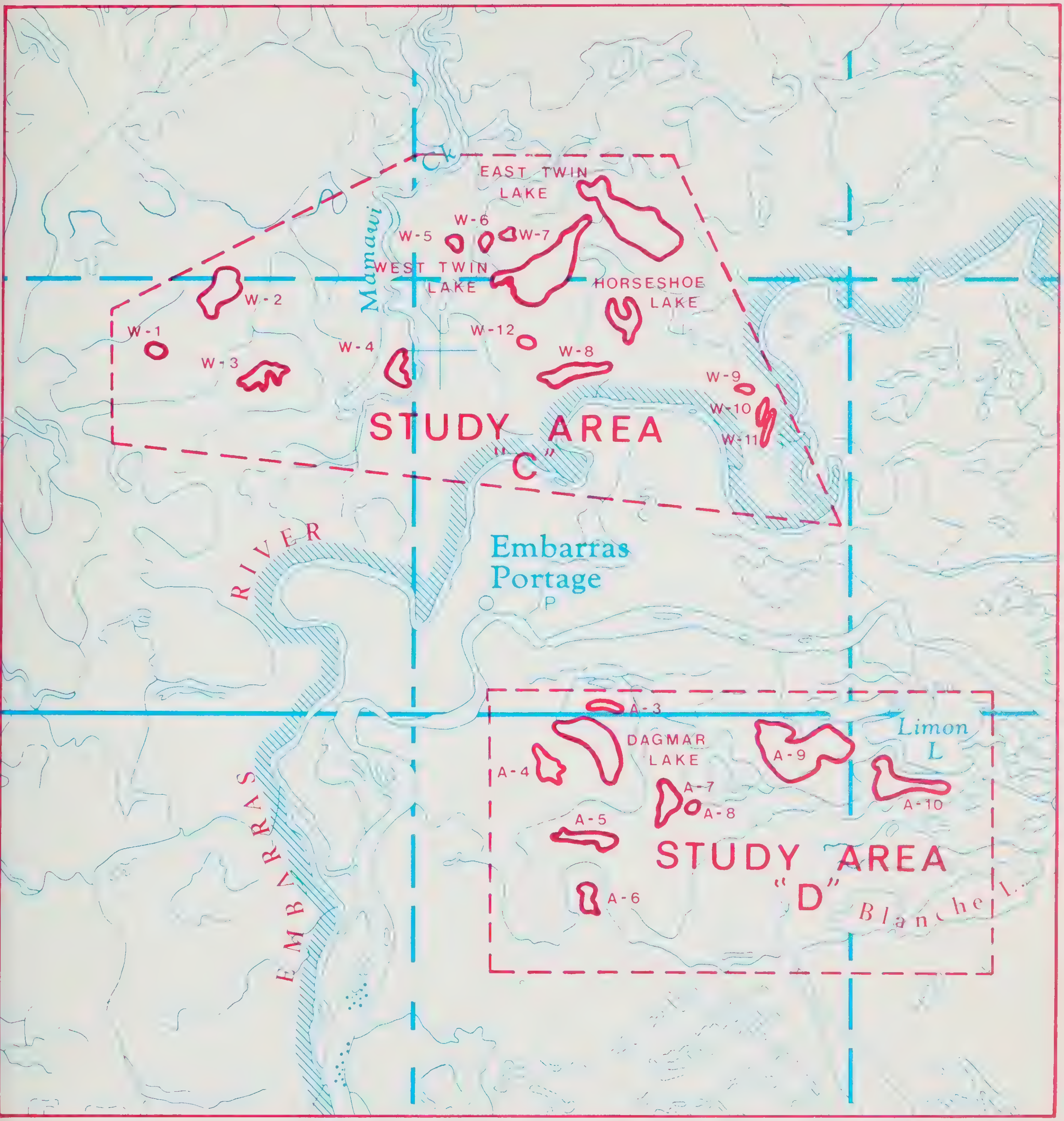

Fig. 5 Study areas "C" and "D" showing lakes surveyed in fall and winter, 1971

The shoreline vegetation of West Twin Lake consists mainly of _Sparganium_, _Acorus_, _Carex_, _Typha_, and _Scirpus_. _Scirpus_ is dominant and most abundant offshore where it extends as two large bands along the length of the lake.

The vegetation of East Twin Lake is similar. _Scirpus_ is dominant and confined mostly to the central portions of the lake. On the shoreline, _Sparganium_ is most abundant followed by _Typha_ and _Equisetum_. The principal submersed genera are _Myriophyllum_ and _Potamogeton_.

METHODS

POPULATION DEMOGRAPHY

CENSUS METHODS

Trapping

All live-trapping was confined to South Egg Lake. Although most of the trapping was done at houses, a few bank runs were also chosen as trapsites. The trapsites were numbered with metal tags and marked with colored flagging tape. The location of each site was then plotted on a map. Traps were set at a particular location for usually five days, or until all muskrats had been recaptured. Intensive live-trapping began on July 17, 1971.

Wire cage traps were baited with plants available at the site and set, usually as doubles. Wherever possible, traps were placed on or near the house. In areas where associated emergent vegetation could not support the weight of the traps, 2" x 8" boards were used as floats on which one or two traps could be fastened. A willow pole was inserted into a hole through a board and forced into the substrate in order to stabilize the floating traps.

During the initial three weeks of the study, traps were checked and reset early each morning and late each afternoon. However, since daytime trapping success proved to be low, this method was discontinued. Subsequently, traps were set in late afternoon and checked early the following morning.

Each captured muskrat was placed in a wire mesh cone and a

numbered fingerling tag was attached to each ear. The muskrat was then weighed, using a 2000-gram spring balance, sexed by examination of the external genital area, and aged by pelt primeness. The tail was measured to the nearest 1/8 inch. For all captures, sex, age, weight, tail length, ear tag numbers, site number, and date of capture, as well as any supplementary information, was recorded.

In addition, houses were opened periodically to determine the approximate time when litters were born and the number of litters produced in a single season. Live-trapping was discontinued on September 21 when near-freezing nighttime temperatures caused an increase in juvenile mortality.

During the period from November 18 to December 9, 1971, muskrats were kill-trapped out of five runs on East Twin Lake, five houses on West Twin Lake, and five houses on North Egg Lake. Runs were identified as a line of push-ups extending from the bank. Trapping of bank runs at East Twin Lake was accomplished by placing a trap in one of the push-ups of a run. On West Twin and North Egg Lake, single traps were placed within houses. Traps were left at each site for a minimum of four days after the last muskrat was captured.

While the spring work was being conducted in 1972, a technician spent 10 days accompanying a local resident, Daniel Marcel, on his daily trapchecks at South Egg Lake. The prime objective was to recover tags from animals which had been live-trapped in the previous summer. Daily records were kept of the tagged and

untagged muskrats taken, the numbers of the ear tags, and the numbers of the houses from which each muskrat was trapped.

Aerial Reconnaissance

During October, 1971, a detailed survey of the muskrat population on the Delta was conducted from a Piper Super Cub aircraft. The muskrat population was estimated using Doziers' (1948) method of house counts.

Areas intensively covered in the survey were the Birch River Delta, the east side of Lake Claire, north of Mamawi Lake to the Embarras River, west of Fletcher Channel to the Embarras River, east of Chenal des Quatre Fourches to the Peace River and Riviere des Rochers, the Chipewyan Indian Reserve, and along the east edge of Big Point Channel (Fig. 1). The Baril Lake and Sweetgrass area north to the Peace River, and the tree line east of Lake Claire extending to the Embarras River, did not receive intensive coverage (Fig. 1).

Parallel transects were flown approximately 600 feet apart and 100 to 150 feet above ground at an average airspeed of 60 miles per hour. Occasionally, this method was modified depending on relief of the area, size and shape of the lake or slough, density of emergents, and the height of trees, if present. For example, a large lake with emergents confined to the shoreline could best be surveyed by circling it above the shoreline. Where emergents were dense, lines were flown across the lake approximately 300 feet apart and 100 feet above ground.

A number of areas chosen randomly were censused a second time by helicopter to compare the effectiveness of both aircrafts. Areas surveyed were North Egg Lake, Frezie Lake, Big Lake, East Twin Lake, West Twin Lake, and those lakes designated by the authors as A-2, R-2, R-4, R-11, W-2, and W-3 (Figs. 2, 4, and 5). The methods employed with helicopter were similar to those using fixed-wing except that parallel transects, approximately 150 feet apart and 60 feet above ground, were flown.

Ground Reconnaissance

Prior to freeze-up, South Egg Lake was thoroughly searched by canoe. In September, two crews, each consisting of two men, located active houses, marked and tagged them, and plotted their location on a map.

To check the efficiency of aerial counts, the search for houses was continued by snowmobile after freeze-up (Oct. 25). The Twin Lakes, North Egg Lake, South Egg Lake, and lakes W-1, W-2, W-3, R-11, R-30, R-31, and R-32, which had previously been censused from fixed-wing, were surveyed on the ground. All houses and push-ups were checked by probing with a rat spear. If an open plunge hole was found, the site was considered to be in use; if the plunge hole was frozen, it was regarded as inactive. The distinction between houses and push-ups and the function provided by these structures has been discussed in detail by Fuller (1951).

Winter Mortality Factors

In spring, 1971, three crews, each consisting of a C.W.S. technician and a local resident, measured water and ice depths at muskrat houses and push-ups in study areas "A", "B", and "C" (Fig. 1). Each site was checked to determine whether it was active or inactive. A hole was drilled through the ice approximately 10 feet from the site, using a power auger. The depth of snow, ice, and ice plus water were determined to the nearest 0.05 feet with a measuring rod calibrated in tenths of a foot. The bottom type (soft mud or frozen mud) was also noted.

This procedure was repeated in November and December, 1971. All active houses and runs were located on West Twin Lake, East Twin Lake, Horseshoe Lake, North Egg Lake, and lakes W-1 to W-12 inclusive, R-11, R-28, and R-30 to R-35 inclusive (Figs. 2-5).

These same sites were revisited in March, 1972. Snow, ice, and water depth measurements were again recorded. In addition, signs of food shortage and predation were noted.

In both years, data obtained at houses were analyzed statistically to determine the effect of ice depth, water depth, and bottom type. The number of active and inactive houses within four depth classes (0.0 - 1.0 feet; 1.1 - 2.0 feet, etc.) and varying degrees of ice composition (50-59 percent; 60-69 percent, etc.) were tabulated, such that differences between classes could be tested using a Chi-square contingency test (Steel and Torrie, 1960). Data from push-ups were analyzed statistically in 1971, but not in 1972.

In fall, 1971, several lakes surveyed by helicopter were sampled for water depth to aid the assessment of the Delta's capability of over-wintering muskrats. The lakes sampled were South Egg, Frezie, North Egg, East Twin, West Twin, Horseshoe, W-1 to W-12 inclusive, A-1 to A-10 inclusive, R-11, and R-30 to R-35 inclusive, in study areas "A", "B", "C", and "D" (Figs. 2-5).

The helicopter landed on each lake at three to five arbitrary points along a roughly linear transect. A gauge was lowered into the water and the depth was read. Depths were measured near the shoreline and in the center of the lake.

HABITAT EVALUATION

VEGETATION COMPOSITION AND WATER DEPTH

The various habitat types were delineated on a transparent overlay of a 1971 aerial photograph of South Egg Lake (scale, 4" =1 mile). Area of each type (to the nearest acre) was measured with a grid square and rechecked with a planimeter. Shoreline distances, as defined by the presence or absence of dense emergent cover, were determined with a map measurer.

Random depths were measured within each stand and along linear transects of the lake to determine the relationship between water depth and habitat type.

In August, 1971, three transects were run by canoe across South Egg Lake: one from the southeast shore (near the portage) to the shore of the west snye, one from the northeast to the northwest

shore, and another from the north central to the south central shore (Fig. 3). The canoe was headed toward a fixed point on the opposite shore, and a compass was used to maintain a relatively straight course. Water depths were measured at approximately 15-yard intervals along each transect, beginning 10 feet from the shoreline. Where the line crossed a particular vegetative type, depth readings within that interval were noted. Emergent vegetation near the location of the depth reading was recorded.

All depths were measured with a pole calibrated in tenths of a foot. Since the firmness of the lake bottom varied from very soft to hard, the pole was slowly lowered into the water until a slight resistance to its weight could be detected. Depths were read at this point.

A Water Resources gauge, installed in the lake in early July, was read daily so that all depth measurements could be adjusted to a value at freeze-up.

VEGETATION UTILIZATION

In an attempt to appraise the importance of each habitat type, a study concerning vegetation preferences for food and house construction was carried out on South Egg Lake.

The relative abundance of emergent species at houses and runs was determined by measuring the linear distances occupied by each emergent species along a transect. Vegetation around houses was assessed by using a house as the center point of two 50-foot transects. The lines were run at right angles from north to

south and east to west. The linear extent of all emergent species and open water along the transect, and the number of intervals of open water, were recorded.

Linear transects of muskrat runs which entered a shoreline of mixed emergents were also set up. A 50-foot length of tape was extended from the center of the mouth of an active muskrat run to its terminus at the shoreline.

All houses and runs sampled in each habitat type were chosen at random. All measurements were recorded to the nearest tenth of a foot. The abundance of submerged species was assessed subjectively.

The number of houses within each of the four major habitats was noted. A detailed subjective description of vegetation at or near houses, and the composition of construction materials, was also documented.

Selected areas in each of the four major habitat types were live-trapped. Rectangular sample plots, 600 feet by 300 feet (or equivalent), were staked out from canoe in each of the Scirpus, Phragmites, and mixed emergent stands. A 300-foot by 150-foot plot was used in the smaller Equisetum stand. The borders of all study areas were delineated with willow poles and colored flagging tape.

Twenty traps were set in each of the three large sample plots and rechecked for a period of five nights (100 trapnights). In the Equisetum study area, which was one-quarter the size of the

others, five traps per night were used (25 trapnights). Traps were set, usually as doubles, although the number at each site (two, four, or six) varied with the abundance of muskrat sign. Favored sites were houses, runs, and feeding platforms. Where muskrat activity appeared low, traps were placed in locations selected at random within the sample area.

All habitat types were trapped in during the same time interval. Two samples were obtained for each study area, one during the August 16 - 20 period, and another during the September 16 - 21 period.

Importance of the shoreline was also assessed. The shoreline type chosen consisted of a mixture of emergent species extending a minimum of 15 yards lakeward from the water's edge. A 300-yard segment was marked off along the southwest shore of the lake. Fifty traps were set as doubles at 10 - 15 yard intervals along the shoreline segment for two consecutive nights (100 trapnights). Where possible, traps were set at the mouth of an active muskrat run. The number of runs within the sample area was noted.

POPULATION DEMOGRAPHY

POPULATION ESTIMATE OF SAMPLE

Production Per House

During the period July 4 to September 21, live-traps were set near 99 active houses on South Egg Lake. From these, 434 muskrats were tagged and recaptured 406 times for a total of 840 successful live-trapping attempts (roughly 3,000 trapnights). Fifty-six of the 99 houses were trapped out, producing 280 muskrats or an average of 5.0 muskrats per house. Winter kill-trapping from a combined total of 10 houses on West Twin and North Egg Lakes yielded 51 animals, or 5.1 muskrats per house (Table 1).

These results support the data obtained by other researchers (Fuller, 1951; Dozier, 1948; Errington, 1962). Density and production undoubtedly vary from one lake to the next depending on the type and abundance of vegetation, availability of food and building materials, size of house, water depth, and population tension. However, it is felt that a value of 5.0 muskrats per house is a reliable figure for the entire Delta.

Dave Westworth, who worked on North Egg Lake in the summer of 1971, obtained a value of 2.4 muskrats per house compared with the authors' winter estimate of 3.8 muskrats per house on the same lake (Table 1). Reduced mobility of muskrats after freeze-up might have increased the efficiency of kill-trapping.

Table 1. Number of muskrats in houses and runs on four Delta lakes.

Lake	Method	Location of Trapsites	No. of Houses or Runs Trapped	No. of Muskrats Captured	No. of Muskrats Per Run	No. of Muskrats Per House
South Egg	Live-trapping	Houses	56	280		5.0
South Egg	Live-trapping	Runs	5	18	3.6	
West Twin	Kill-trapping	Houses	5	32		6.4
East Twin	Kill-trapping	Houses	5	19		3.8
North Egg	Kill-trapping	Runs	5	16	3.2	

Production Per Bank Run

Eighteen muskrats were live-trapped from five active runs on South Egg Lake in the summer for an average of 3.6 muskrats per run. This compares favorably with fall kill-trapping at East Twin Lake which yielded 16 animals or 3.2 muskrats per run (Table 1). The figure for South Egg Lake is conservative, since two of the five runs were trapped (two traps per run) for a period of only three days.

Sex and Age Ratios

For the entire summer's trapping (July 4-September 21), the ratio of juveniles to adult females was 10.3:1; the ratio of juvenile males to juvenile females was 2.5:1; and the adult male to adult female ratio was 1.3:1 (Table 2).

Trapping success for the month of July was generally low and probably not representative of the population, since many juveniles were observed inshore among *Salix* stands which were not intensively trapped. The data include muskrats from some houses which were not completely trapped out.

During the August 2-September 21 period, after the second litter had become independent, an increase in live-capture success was evident (Table 3). For this period, the ratio of juveniles to adult females was 12.5:1.

In the winter trapping period, 67 muskrats were captured: 51 males, 10 females, and 6 unrecorded or of unknown sex. The overall ratio of males to females was 5.1:1. These muskrats were

Table 2. Total number of muskrats tagged at South Egg Lake, summer 1971.

	Males	Females	Unknown	Total
Adults	44	34	7	85
Juveniles	224	90	35	349
Total	268	124	42	434

Juveniles : Adult Female - 10.3:1

Juv. Male : Juv. Female - 2.5:1

Adult Male : Adult Female - 1.3:1

Table 3. Muskrats tagged at South Egg Lake, August 2 - September 21, 1971.

	Males	Females	Unknown	Total
Adults	19	23	-	42
Juveniles	197	63	27	287
Total	216	86	27	329

Juveniles : Adult Female - 12.5:1

Juv. Male : Juv. Female - 3.1:1

Adult Male : Adult Female - 1:1.2

not aged.

The preponderance of males captured can be attributed to a number of factors. Firstly, differences in behavior related to sex may be important. Adult males are generally more mobile than adult females and are therefore more susceptible to trapping. It seems likely that certain forms of behavior (such as curiosity and mobility) are more inherent in the male population. Secondly, females are confined to houses during the pre- and post-natal period. The one-month dependency period of each litter corresponded to a low incidence of captured females. Thirdly, there may actually be more males in the population. This would be advantageous to insure that a maximum number of females are fertilized. Other workers (Fuller, 1951; Stevens, 1953; Errington, 1962) have found high numbers of males in the muskrat populations they studied.

Number and Size of Litters

Observations of the muskrats on South Egg Lake provide evidence that two well-defined litters and in some cases a third litter were produced during the summer.

On June 10, 11, and 12, several houses were opened and five nests containing kits were located. All of the kits were estimated to be between 6 and 14 days old. This indicates that the birth of the first litter began during the last week of May, although most births probably took place in the first week of June. Since intensive live-trapping did not begin until July 17, the period of dependency of first litter young could not be

determined, but Ruttan (pers. comm.) estimated that it was 30 days. First litter juveniles became independent during the last week of June, at the earliest, and more commonly in the first week of July.

The second litter appeared during the last week of June and first week of July. Houses opened on June 29, July 10, and July 16 contained kits estimated at 1, 4, and 21 days old. Second litter kits first appeared in traps early in the last week of July but were more common at the beginning of August.

Signs of a third litter were scarce. Parturition of the third litter was expected to take place in the first or second week of August. Eight houses were opened during early and middle August, but no third litter young were found. Four adult females captured at this time were examined for signs of abdominal swelling, vascularized mammae, and increased weight, but no signs of pregnancy were noted. However, on August 11, Mr. Daniel Marcel observed an adult female which he said was pregnant and close to term. On September 21, a male juvenile weighing 150 grams was captured. The pelage of this animal was fluffy, dark, and lacking in guard hairs. All trappers agreed that it was a third litter muskrat not much more than four weeks old.

In the past, there has been widespread disagreement among experts concerning the number of litters produced in a single season. Fuller (1951) maintained that two major litters were born while the occurrence of a third is unlikely or, at best, sporadic. The results of this study concur with Fuller's

hypothesis.

In contrast, Westworth (pers. comm.) witnessed the appearance of three well-defined litters at North Egg Lake. Differences between Westworth's results and those obtained at South Egg Lake can be explained largely by habitat differences. South Egg Lake flooded in July, 1971, while North Egg Lake was relatively unexposed to high water. Flooding at critical periods has been shown to inhibit muskrat production (Bellrose and Low, 1943). The fact that the variety and abundance of muskrat foods is less on North Egg than on South Egg seems to reinforce the importance of fluctuating water regimes.

In this study, figures for litter size are based on live-trapping data obtained at South Egg Lake. Since the young to adult female ratio was 12.5:1, the mean number of juveniles per female in each litter would be 6.2. In five occupied nests opened during mid-June, the number of newborn young ranged from 4 to 8. The average was 5.8.

Placental scars were not counted since very few female adults died during live-trapping. Only one carcass of a pregnant female was examined. It contained four embryos - two in each uterine horn.

An attempt to separate litters statistically by weight and tail length proved unsuccessful since variations in time of birth, number of young produced by a single female, rate of growth of juveniles, and weight losses due to prolonged periods in the live-traps, caused varying degrees of overlap between litters.

Average litter sizes of the North Egg muskrats were 8.9, 7.2, and 5.0, for first, second, and third litters, respectively; the overall average was 7.0 (Westworth, pers. comm.). Results from both lakes support Fuller's (1951) estimate of 6 to 8 young per litter.

While the number of young per litter and the number of litters was higher at North Egg Lake, the young to adult female ratio was similar in both cases -- 12.5:1 at South Egg and 12.1:1 at North Egg (Westworth, pers. comm.). This would indicate greater summer mortality at North Egg Lake. Westworth (pers. comm.) observed evidence of intraspecific strife among the muskrats of North Egg Lake, which included fighting, cannibalism, and competition for low quantity but high quality foods (*Scirpus* and *Sparganium*).

At South Egg Lake, intraspecific strife was minimal. Occasionally, adults (especially males) were found with scars that had probably been inflicted during the previous breeding season. The production of a third litter on some Delta lakes, then, does not necessarily mean an increase in population number since over-crowding can be an inhibitory factor.

DELTA POPULATION ESTIMATES

Aerial and Ground Census

A total of 3,394 active muskrat houses were counted from fixed-wing aircraft and an additional 200 houses were estimated in the Baril Lake and Sweetgrass areas. This resulted in a total house

count for the entire Delta of 3,594, which included 1,413 houses in Alberta, 1,204 on the Chipewyan Indian Reserve, and 977 in Wood Buffalo National Park.

The total ground count for North Egg Lake, West Twin Lake, East Twin Lake, and lakes W-1, W-2, W-3, W-12, R-11, R-30, R-31, and R-32 was 781 houses compared to 420 by fixed-wing. The ground:air conversion factor was therefore 781:420 or 1.9:1 (that is, approximately 50 percent of all muskrat lodges were located by fixed-wing aircraft).

The projected estimate, on the basis of ground counts, would be 3,600 x 2 or roughly 7,200 houses (2,826 in Alberta; 2,408 on the Chipewyan Reserve; and 1,954 in Wood Buffalo Park). Of the total number of sites sampled in the early winter, 12.5 percent were bank runs. Theoretically, this amounts to 1,030 bank runs on the Delta.

On the basis of five muskrats per house and three muskrats per run, the 1971 fall muskrat population on the Peace-Athabasca Delta was approximately 40,000 (- 10,000), comprising 15,340 animals in Alberta, 13,070 on the Chipewyan Reserve, and 10,595 in Wood Buffalo Park.

The lakes having the highest muskrat populations were North Egg, South Egg, Big Lake, and Frezie Lake (Table 4). Muskrat numbers were greatest in the Chipewyan Reserve area (subdivision F; Appendix I) and west to the Embarras River (subdivision B). Densities ranged from 0.1 muskrats per acre of emergent vegetation in subdivisions E and I to 11.4 muskrats per acre

Table 4. Number of active muskrat houses and bank runs (based on ground counts); and estimated muskrat population of representative Delta lakes, 1971.

Lake	Active Houses	Bank Runs	Estimated Population
Study Area A			
R-11	78	-	390
R-31	33	-	165
R-32	50	-	250
R-33	74	-	370
South Egg	429	?	2145
*Big Lake (and surrounding area)	444	-	2220
*Frezie	276	-	1380
Study Area B			
North Egg	450	4	2260
Study Area C			
W-1	6	1	35
W-2	15	-	75
W-3	14	12	105
W-12	1	-	5
West Twin	34	21	235
East Twin	30	21	215

*These lakes were surveyed only from the air. Figures are therefore estimated on the basis of a ground : fixed-wing conversion ratio of 2:1.

emergent vegetation in subdivision B (Table 5).

Very little or no muskrat activity was observed on the larger lakes such as Richardson, Mamawi, Baril, Otter, Hilda, and Welstead. All were very shallow and had few, if any, emergents in water.

Validity of Estimates

Although approximately 50 percent of the actual number of houses (based on ground counts) were located using fixed-wing aircraft, efficiency of aerial survey varied with the type of habitat. In lakes which hosted an abundance of *Scirpus*, fixed-wing efficiency was, in many cases, 100 percent. However, if the area surveyed contained emergents in high density (e.g., *Phragmites*, *Carex*, etc.), efficiency was sometimes very low. On North Egg Lake, only 21 percent of the houses were observed from the air. The dominant emergent species of this lake is *Carex*.

As expected, aerial reconnaissance by helicopter proved to be more effective than that by fixed-wing aircraft. On the average, 18 percent more houses were located by helicopter than by fixed-wing (Table 6).

The estimated fall population is based on a number of important assumptions:

(a) averages of five muskrats per house and three muskrats per bank run are accurate indices of the entire Delta population.

Table 5. Results of air and ground counts, estimated populations, and muskrat densities in sub-basins, Peace-Athabasca Delta, 1971.

Sub-basin*	Houses Counted (by fixed-wing)	Adjusted Count (ground:fixed-wing=2:1)	Estimated No. of Bank Runs	Estimated Population	Emergent Vegetation (acres)	Density (muskrats/acre emergent vegetation)
A	99	198	28	1075	522	2.1
B	914	1828	261	9925	868	11.4
C	150	300	43	1630	589	2.8
D	37	74	11	405	1875	0.2
E	12	24	3	130	2400	0.1
F	1498	2996	428	16265	2426	6.7
G	227	454	65	2465	2415	1.0
H & J	222	444	63	2410	10784	0.2
I	124	248	35	1345	25928	0.1
K	311	622	89	3375	1796	1.9
Total	3594	7188	1032	39025	49603	Av. = 2.7

*See map of subdivisions in Appendix I.

Table 6. Air counts of muskrat houses on Peace-Athabasca Delta from fixed-wing aircraft and helicopter.

Lake	Helicopter	Fixed-wing	Percentage
W-2	8	7	87.5
W-3	15	14	93.0
East Twin	53	61	115.0
West Twin	51	40	78.0
North Egg	128	94	73.0
Frezie	166	138	83.0
Big Lake area	259	222	86.0
R-2	54	20	37.0
R-4	2	1	50.0
R-11	53	51	96.0
A-2	34	30	88.0
Total	823	678	Av. = 82.0

(b) all active muskrat houses on the lakes studied were located by ground reconnaissance after freeze-up.

(c) a ground-to-air conversion factor of two is an accurate estimate of fixed-wing efficiency.

(d) those lakes surveyed on the ground were representative habitats of the entire Delta (that is, the distribution and quantity of emergent vegetation in these lakes was typical of the whole Delta).

(e) in late fall and early winter, when ground surveys were conducted, the muskrat population was at its peak.

Accurate survey methods are a basic requisite for estimating populations of any animal species. Aerial survey is advantageous because a large area can be covered in a short period of time. However, several factors present problems which must be compensated for.

Firstly, a means of distinguishing "live," or active houses, from "dead," or inactive houses, was necessary (Dozier, 1948). In general, there was no accurate method of assessing house activity from fixed-wing aircraft. However, activity could be determined from helicopter if the machine was propelled at low elevations and low airspeeds. The presence or absence of freshly cut vegetation on the house was used as a criterion for determining whether muskrats were using the house.

Secondly, the size of the lodge was important. Size was found to vary with the type of vegetation in which the house was found.

For example, *Phragmites* and *Scirpus* stems are bulkier than those of *Carex*. Houses constructed of *Scirpus* are correspondingly larger and easier to see from fixed-wing aircraft than are houses of *Carex*.

Thirdly, houses built in the willows, and bank runs or dens which were hidden by over-lying vegetation, were often difficult to see. This was usually the case in heavily flooded areas where tall shrubland was partially submerged and, therefore, converted to suitable muskrat habitat.

Fourthly, while topographical and vegetational features can markedly affect the accuracy of population estimates, variability among observers is also important. Consequently, all aerial surveys in fixed-wing aircraft were done by Allison; all surveys in helicopter by Ambrock. One variable, fatigue of the observer, could not be controlled. In the morning, when the observer was well-rested, the accuracy of aerial house counts was probably greater than that in the afternoon.

For the above reasons, it is felt that 40,000 animals is a conservative estimate of the muskrat population in the Peace-Athabasca Delta.

Evidence for a 10-year cycle of muskrat abundance has been provided by Elton and Nicholson (1942; cited in Fuller, 1951). Fuller, in agreement with this hypothesis, postulated a peak in 1950. A low should have occurred in 1955; another peak in 1960; a low in 1965; and a peak in 1970. While the cycle may not follow as rigid a time span as indicated here, it is thought

that the muskrat population studied in 1971 was in a stage of decline. According to records compiled by the Hudson's Bay Company and the Alberta Game Office in Fort Chipewyan, the lowest muskrat harvest for the 1960-1970 period was 31,532 skins in 1962-1963. The harvest figure is much lower than the actual population figure. The number of furs traded yearly at Fort Chipewyan does not necessarily reflect population trends, since harvest conceivably varies with the number of trappers actively trapping. However, the harvest figure for 1962-1963 is important; it indicates that the total population estimate of 40,000 animals is low compared to recent times. Therefore, it seems that the muskrat population in 1971 approached one of its all-time lows.

WINTER MORTALITY FACTORS

In March, 1971, data were obtained from 1,048 sample sites comprising 319 houses and 729 push-ups. Thirty-seven percent of the houses and 29 percent of the push-ups were considered active. During November and December, 1971, 823 active muskrat houses were sampled on the lakes mentioned. In March, 1972, 601 of these were rechecked and 51 percent were still active. House activity ranged from 21 percent on Lake W-2 to 83 percent on Lake R-35 (Table 7).

The higher percentage of houses active in 1972 (compared to 1971) might be attributed to snowfall. In 1972, there was much more snow and, consequently, less ice than in 1971. As a result, the occurrence of freeze-outs was not as frequent as in the

Table 7. Percentage of active houses on Delta lakes in March, 1972.

Lake	Sample Size	Number of Active Houses	Number of Inactive Houses	Percent Active
North Egg	144	55	89	38
South Egg	77	48	29	62
East Twin	24	18	6	75
West Twin	35	25	10	71
Horseshoe	8	5	3	62
W - 1	4	2	2	50
W - 2	14	3	11	21
W - 3	8	4	4	50
W - 8	7	2	5	29
W - 9	6	3	3	50
W - 10	16	8	8	50
W - 11	4	3	1	75
W - 12	16	5	11	31
R - 11	54	23	31	43
R - 28	29	20	9	68
R - 30	19	15	4	79
R - 31	32	12	20	37
R - 32	51	25	26	49
R - 33	42	21	21	50
R - 34	5	4	1	80
R - 35	6	5	1	83
Totals	601	306	295	Av.= 51

previous year.

Weather Factors

The overflow at South Egg Lake demonstrates the effect of environmental extremes. After freeze-up (early November), heavy snow fell and soon melted. The added weight caused water seepage upward over the surface of thin ice; thus many small houses became partially submerged. Several houses were broken apart at this time as a direct result of the overflow. Subsequently, when the water froze, the damage increased. By spring (1972), 149 of 429 houses tagged in the previous fall had disintegrated. Where a house once existed, only a few construction materials remained frozen in the ice. Some large houses virtually disappeared as a result of the overflow. This situation was not observed on the other lakes studied since the active houses on these lakes were tagged after the thawing and refreezing had occurred.

Snow Depth and Ice Thickness

In 1971, there was a significant linear correlation between snow depth and ice thickness ($r = -0.52$, $p < 0.01$). Average snow and ice depths at houses having water were 0.88 feet and 2.36 feet, respectively. In the following year, mean values of 1.16 feet and 1.92 feet, respectively, for snow and ice depth were obtained.

In 1972, a general relationship was again observed between snow depth and ice thickness, although this was not tested statistically. In shallower lakes, at least, snow depth was

found to be of some importance in maintaining water at houses. Where snow exceeded two feet, water did not freeze completely to the bottom - even in depths as shallow as 1.1 feet. If there was less than one foot of snow, ice attained thicknesses of up to three feet.

Effect of Total Depth on House Activity

The mean total depth of ice and water at active houses in both years was 1.8 feet. The mean total depth at active push-ups in 1971 was 2.8 feet.

There was a definite trend toward increased activity in houses as total depth increased (Fig. 6). In 1971, the critical minimum depth required for optimum muskrat survival was calculated to be 2.5 feet. In 1972, statistical analysis of data from 557 houses revealed that:

(1) The percentage of active houses is dependent on total depth of water and ice in fall (x^2 0.01).

(2) If the total depth of water and ice is less than 2.0 feet, percentage activity is significantly less than in depths greater than 2.0 feet (x^2, p 0.01). A significant difference was also found at the 1.0 foot level. That is, house activity at depths of 0.0 to 1.0 feet was significantly less than that found in the 1.0 - 2.0 foot range (x^2, p 0.01). This relationship also existed when comparing depths of 1.1 - 2.0 feet and 2.1 - 3.0 (x^2, p 0.05). There was no significant difference in house

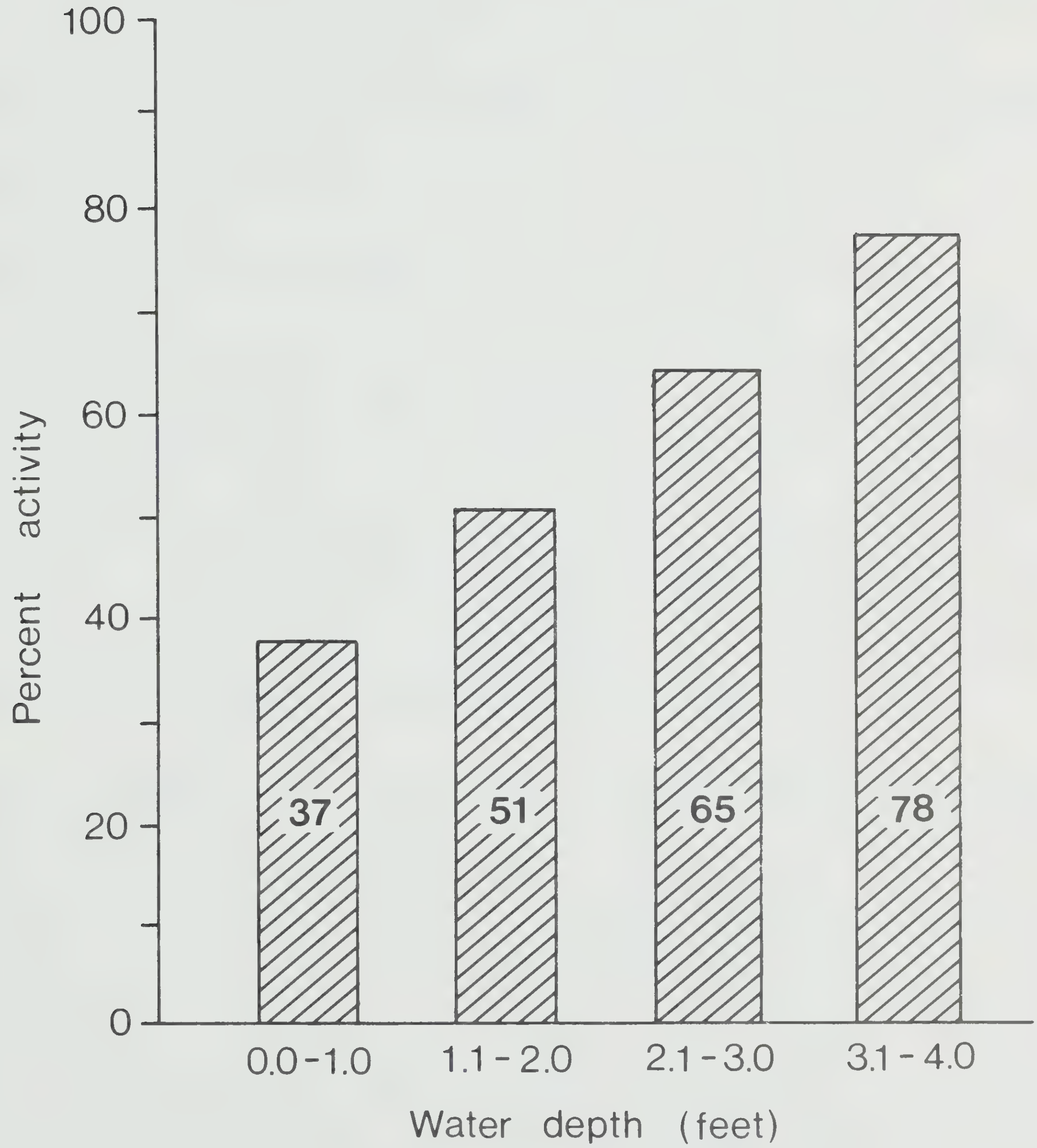

Figure 6. Percentage of active houses at various water depths.

activity between the 2.1 - 3.0 and 3.1 - 4.0 foot ranges, indicating that 2.0 feet is the critical level. Of 48 randomly selected lakes sampled for water depth in fall, 1971, approximately 70 percent had depths below this calculated critical level.

(3) Bottom type (soft or frozen mud) had no significant effect on house activity (x^2, p 0.05).

<u>Effect of Ice Depth on House Activity</u>

The ice-water ratio at houses did not have a significant effect on activity (x^2, p 0.05). Of the sample of 119 active houses at which holes were drilled through the ice in 1971, 71 percent had no detectable water--only frozen mud at the drill site. Occasionally a muskrat runway was struck with the drill bit and found to be completely dry. In the spring of 1972, 44 percent of all active houses had no detectable water (n=306).

While ice depth did not significantly differ between active and inactive houses, this does not indicate it was not important. Where water is frozen to the bottom, availability of food is restricted. This can be overcome to a certain extent by the animals burrowing down into the mud to feed on roots of emergent plants (Errington, 1963; Turner, 1970). If there is an abundance of emergent species nearby, muskrats can survive in the absence of water without a great deal of stress placed on them (Errington, 1963). In many areas, however, habitat conditions were poor; and it is felt that many muskrats were undergoing a critical period of stress even though a great number of houses

were still active where the water was frozen to the bottom.

Predation Effects

Signs of predation were common. Primary predators were mink and coyote; however, instances of predation by foxes, wolves, and otter were also recorded. A few houses were trampled and destroyed by wandering bison.

Predation appeared to be related, in part, to the depth of the lake. Shallow lakes, which were frozen completely to the bottom, were subject to a high degree of predation. This was particularly true of North Egg Lake. Signs of predation on deeper lakes, such as South Egg and Horseshoe, were notably fewer.

In lakes frozen to the bottom, movement becomes so restricted that means of escape are severely threatened. Furthermore, muskrats endangered by freeze-outs may burrow out of their lodges and move onto the surface of the ice, making them susceptible prey to foxes and coyotes (Errington, 1963; Fuller, 1951; Gashwiler, 1948).

Spring Tag Returns

Of 66 animals trapped at South Egg Lake in March, 1972, only 12 had been marked in the previous summer, even though kill-trapping was confined to areas that had been heavily live-trapped. Before spring work was started, local residents had already begun trapping the lake, and many of the muskrats in the study areas had been harvested. Also, early winter overflow had

destroyed or frozen a great number of the fall trapsites, which forced muskrats to move to other areas. Six of the 12 tagged animals had traveled distances ranging from 315 feet to 1.2 miles. All of these moved in toward the shoreline sometime after the second week of September. Mr. Daniel Marcel (pers. comm.) felt that a good portion of the muskrat population of South Egg Lake had begun to inhabit the banks. However, tag returns are insufficient to strongly support his idea.

From 21 houses, an average of 3.2 muskrats per house was harvested. Traps were removed before all animals were captured. This procedure is normally followed by local trappers, since they feel it a necessity to ensure adequate spring reproduction. Mr. Daniel Marcel (pers. comm.) felt that there was usually one muskrat left in each of the houses he trapped. Therefore, the actual number of muskrats per house was approximately four.

Present Overwintering Capacity

House activity is recognized as one of the more accurate means of estimating muskrat populations over a large area (Dozier, 1948); therefore, the percentage of active houses in the spring is regarded as an indication of winter survival of the species. Theoretically, since 55 percent of the houses sampled in 1972 were active, survival should also be 55 percent. However, this figure requires adjustment since mortality due to predation, freezing, old age, and possibly intraspecific strife, occurred at active houses. On the basis of spring tag returns, four out of five muskrats in active houses survived the winter

successfully; therefore, winter survival is calculated to be 44 percent. Using this approach, muskrat survival is shown to be highly dependent on the total depth of ice and water (Table 8). The estimated breeding population without spring trapping for April, 1972, is 17,000 - 22,000 animals. It is assumed, here, that survival of bank muskrats is the same as that of house muskrats. It should also be noted that 44 percent is an approximated value for several reasons:

(a) Some muskrats can move successfully from frozen houses to banks or to other houses. Generally, muskrat movement during the winter is minimal on most of the Delta lakes because these lakes are shallow (less than two feet). Exceptions might be South Egg Lake, Frezie Lake, Dagmar Lake, and Horseshoe Lake, where water is not completely frozen to the bottom. There are indications that some muskrat movements on South Egg Lake were extensive. Nevertheless, muskrats are generally believed to have small home ranges (Errington, 1963).

(b) Local trappers have cited examples of muskrats seeking refuge from freeze-outs by digging out of their houses and constructing temporary dens on the ice under the snow. The extent to which this occurs is not known, but it could affect the survival estimate.

(c) Intraspecific strife prior to the breeding season (at or before breakup) can contribute to added spring mortality (Errington, 1963). Field work was completed each year

Table 8. Estimated spring and winter survival of Delta muskrats at varying water depths. Confidence limits are at 95 percent level.

Depth Class (feet)	Sample Size	Percentage Survival
0.0-1.0	196	30 ± .06
1.1-2.0	176	41 ± .07
2.1-3.0	149	51 ± .08
3.1-4.0	30	61 ± .18

before the breeding season began. The frequency of fighting among males is directly associated with the population density, and in years where muskrat numbers are low, it is considered to be unimportant (Fuller, 1951). Since the populations studied in 1971 and 1972 were low, adult mortality during breeding was considered to be minimal.

Accurate harvest estimates were difficult to obtain since a few local trappers shipped their pelts out for auction. Fur records from the Alberta Fish and Wildlife Division in Fort Chipewyan and Wood Buffalo National Park headquarters in Fort Smith indicate that 14,260 furs were sold to both the Hudson's Bay Company and a private fur dealer in Fort Chipewyan. This included 1,750 furs from Wood Buffalo National Park and 12,510 from the Alberta portion and Chipewyan Reserve combined. In addition, approximately 4,000 muskrat skins were shipped to Edmonton or Regina for fur auction. The total number of pelts taken for the 1971 - 1972 period was about 18,500.

Monthly fur records from the Alberta Fish and Wildlife Division indicate that approximately 30 percent or 5,550 muskrats were trapped prior to the end of March, 1972. These have already been included in the winter mortality estimate for 1971 - 1972. The remaining 13,000 pelts were spring-trapped. Therefore, the actual breeding population for spring, 1972 (including spring trapping), is between 4,000 and 9,000 animals, indicating that mortality due to trapping was also an important factor reducing muskrat numbers over the winter.

It is interesting to note that the harvest value for Wood Buffalo National Park (1,750 pelts) is much less than in the previous year (7,906) and greatly reduced from 1965-66 (144,907).

EFFECTS OF SUMMER FLOOD

During mid-July (1971), the Delta, especially the Athabasca portion, experienced the most extensive flooding since the construction of the W.A.C. Bennett Dam. While flood waters were not as high as those of the 1930's, a number of perched basins which had previously become dry, or nearly dry, were replenished by the overflow of major Delta rivers.

Water levels on South Egg Lake rose abruptly, beginning July 15 and reached a peak by July 22. At the end of the July 15 - 22 interval, the water had risen in excess of four feet. After this peak, lake waters declined to a new level by August 13, resulting in the addition of 1.5 feet of water to the lake (Fig. 7).

Short-Term Effects

The rapid influx of water exerted immediate pressure on the South Egg Lake muskrat population. Clumps of emergent vegetation (*Phragmites*, *Acorus*, *Sparganium*, and *Typha*), intolerant of extreme changes, became uprooted, floating masses. Shorter emergents, such as *Equisetum*, were completely covered by water.

Several muskrat lodges rose with the water and in a short time disintegrated to become floating piles of vegetation. Other lodges were torn apart or blown into the shoreline by strong wind and wave action. Bank runs and bank dens were all but eliminated.

A noticeable shift of the muskrat population toward the

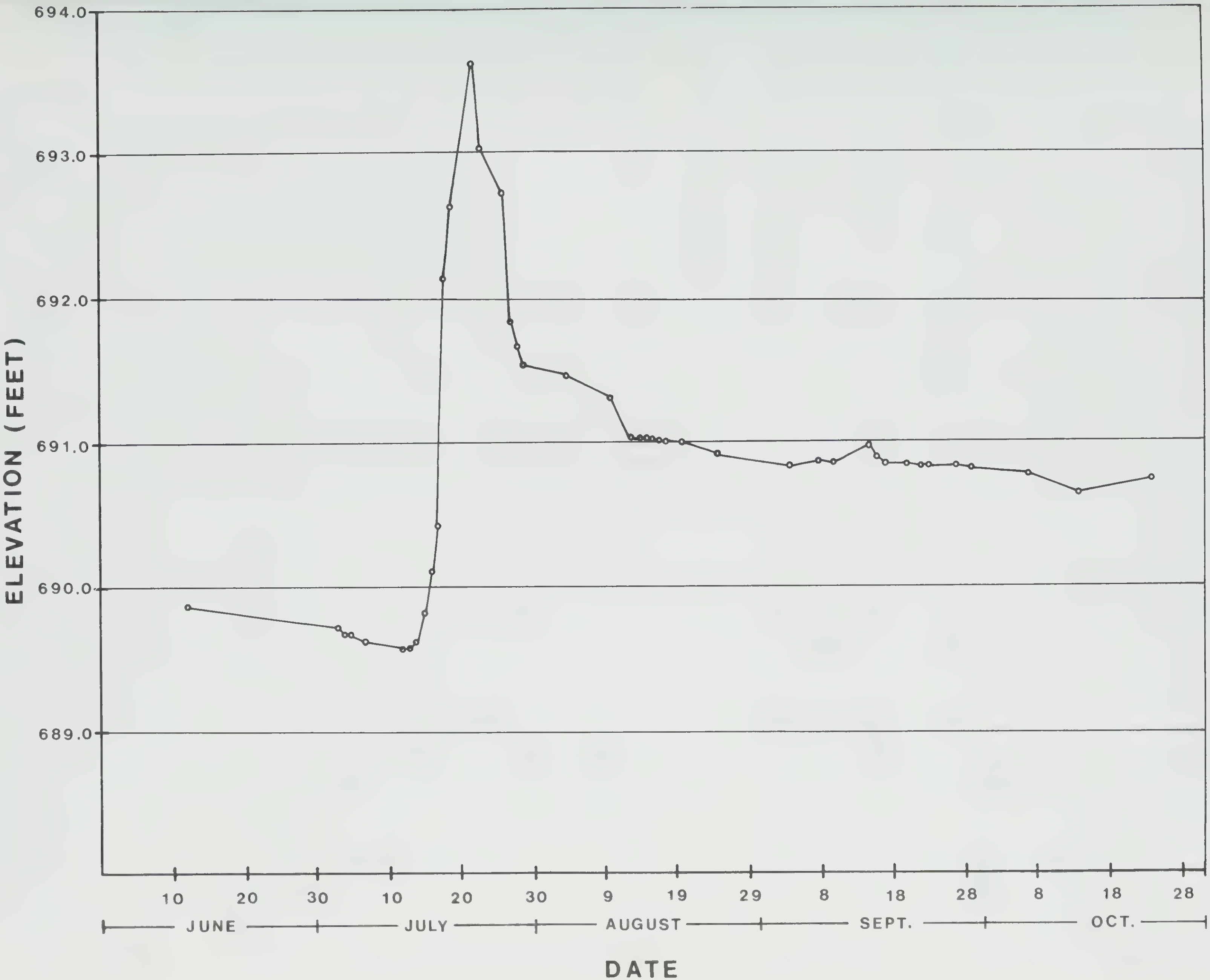

Fig. 7 Fluctuations in water level on South Egg Lake in summer and fall, 1971.

immediate shoreline was observed. First-litter juveniles (in particular) sought refuge among the willows on the periphery of the lake. The stress placed on young second-litter kits probably caused greater mortality than that found in the first litter. A floating muskrat house opened July 16 contained two second-litter kits still dependent on maternal care. The house had apparently been abandoned by the female.

This situation did not seriously increase population tension. There were few signs of intraspecific strife, probably because the shoreline still afforded an abundance of muskrat food.

Long-Term Effects

The process of flooding and corresponding release of emergents from the substrate has probably been typical of South Egg Lake's history. Much of the marsh vegetation can exist in a healthy condition on floating mats (Sharp, 1951; cited in Townsend, 1965). However, like the ponds of the Cumberland marsh (Townsend, 1965), there appears to be a general trend toward a gradual decrease in the quantity of marsh vegetation. Emergents, such as *Scirpus* and *Phragmites*, are slowly being thinned out in the central portions of the lake which were once heavily colonized in drought years.

The recent flooding could be beneficial for the next three or four years. The recharging of lakes will increase winter accessibility of emergents, such as *Scirpus* and *Typha*, which override the already extensive grass-sedge-willow communities as important muskrat food. Muskrat numbers are expected to increase

in the fall of 1972 and 1973. However, a freak flooding similar to the one which occurred in 1971 cannot be expected to sustain high muskrat populations indefinitely. Muskrats depend on periodic flooding to refill marshes. If this does not occur their habitat will continue to diminish.

HABITAT EVALUATION

Vegetation Composition and Water Depth

All habitat types on South Egg Lake were characterized by differences in tolerance of water depth (Table 9). The depths shown are those adjusted to October 24, one day before South Egg Lake froze. Although the ranges overlap, *Scirpus* exhibited a definite preference for deeper water while *Phragmites* was most prevalent offshore and along the old river channel. Both *Equisetum* and the emergent species composing the mixed stand were confined to the shallower waters of the littoral zone (Fig. 3).

The upper limits of tolerance (Table 9) indicate that most established emergents, which are prime muskrat food, could survive in water as deep as 2.5 feet. This is extremely important since muskrats appear to lack foresight in their selection of locations for building houses. Houses may be constructed in water depths ranging from one inch to greater than four feet, as long as there is a plentiful vegetation supply nearby. Consequently, houses are often built where food supply is adequate but water depth is inadequate for year-round survival.

Vegetation Utilization

Linear measurements of vegetation were obtained at 14 houses and 1 muskrat run (Table 10). The percentages of abundance of emergent species are calculated separately from measurements

Table 9. Relationship of water depth and habitat type on South Egg Lake, 1971.

Habitat Type	Area (acres)	Sample Size	Range (ft.)	Mean
Mixed emergents	327	167	0.3 - 4.0	2.7
Phragmites sp.	41	100	1.4 - 4.2	3.2
Scirpus sp.	222	82	2.4 - 4.6	3.9
Equisetum sp.	24	24	1.9 - 3.4	2.6

Table 10. Relative abundance of emergent and submergent species at fourteen houses and one muskrat run on South Egg Lake.*

Habitat Type:	Mixed	Scirpus	Phragmites	Equisetum	Shoreline
Sample Size:	4 houses	4 houses	4 houses	2 houses	1 bank run
Species					
Typha	14.9				11.7
Scirpus	13.5	53.5			
Equisetum	10.8	0.4		72.0	7.3
Phragmites	3.5		47.8	0.5	
Sparganium	1.7			1.7	1.1
Acorus	0.8				6.4
Polygonum	0.2			1.1	
Carex					15.2
Salex					0.4
Other					Dryland & Grass 11.2
Submergents	Myriophyllum & Potamogeton >60		Myriophyllum & Potamogeton n.s.40		Myrio-phyllum n.s.50
Open water	54.0	46.1	52.2	24.7	46

* All figures are expressed as a percentage of the sum of all linear measurements in each habitat type.

within each stand.

With few exceptions, houses were constructed of the available plant material at the site and all marsh species were utilized. However, muskrats showed a preference for _Phragmites_, _Typha_, _Scirpus_, and _Equisetum_. Submersed species (_Potamogeton_ and _Myriophyllum_) were utilized to a moderate degree.

There were 429 active lodges on South Egg Lake at freeze-up. Densities (muskrats per acre of emergent vegetation) showed the following situation: _Phragmites_ was the most important habitat (density 12.5), followed by _Equisetum_ (7.5), mixed emergents (3.5), and _Scirpus_ (1.5; Table 11). Densities were calculated using a value of 5.0 muskrats per house.

The overall use of the four habitat types, derived from sample live-trapping within each stand, is different from the above production estimates (Table 12). In the summer sample (August 16 - 20), _Phragmites_ had the highest use index followed by the mixed emergent stand, _Equisetum_, and _Scirpus_. Differences between _Equisetum_ and _Scirpus_ use were minimal.

In the fall (September 16 - 21), _Phragmites_ remained about the same while the mixed emergent stand increased to equal importance. Muskrat use of _Scirpus_ increased considerably from summer to fall, surpassing _Equisetum_, which remained comparatively low (Table 12).

The indices of habitat use were determined by assigning a value of 1.0 to the stand in which the least number of muskrats were

Table 11. Number of muskrats per acre habitat type on South Egg Lake, summer, 1971.

Habitat Type	Area (acres)	Number of Houses	Houses/Acre	Muskrat/Acre
Equisetum	24	35	1.5	7.5
Scirpus	222	74	0.3	1.5
Phragmites	41	102	2.5	12.5
Mixed emergents	327	214	0.7	3.5

Table 12. Comparative use of four habitat types by muskrats on South Egg Lake, summer, 1971.

		Aug.16 - Aug.20		Sept.16-Sept.21	
Habitat Type	Number of Trapnights	Number of Rats Trapped	Index of Use	Number of Rats Trapped	Index of Use
Equisetum	25	4 (16)*	1.1	6 (24)*	1.0
Scirpus	100	15	1.0	44	1.8
Phragmites	100	36	2.4	56	2.3
Mixed emergents	100	29	1.9	54	2.3

*The values recorded in brackets for *Equisetum* are the actual number of muskrats captured multiplied by four since the number of trapnights in *Equisetum* was one-quarter that of the other habitat types.

trapped. The sum total of muskrats captured in each of the other types of stands was then divided by this number. The data includes both first-capture and recaptured muskrats.

The indices of habitat use differ somewhat from the findings of other investigators (Errington, 1941; Bellrose, 1950). *Phragmites* is not recognized as a highly preferred muskrat food. However, heavy "mining," which was prevalent within pure *Phragmites* stands on South Egg Lake, is indicative that it may be an important nutritive material. Bellrose (1950) found that *Phragmites* was one of the least sought-after marsh plants by muskrats in the ponds of the Illinois River Valley. The most important ones were *Typha*, *Scirpus*, and *Polygonum*. These are also regarded as prime muskrat food by Errington (1941) and Fuller (1951). In this study, differences in food preference are partially explained by availability and access. Since *Phragmites* is the dominant emergent of South Egg Lake and since muskrats are very versatile feeders, the results are not surprising.

Scirpus ranked low, probably because of its location in deeper water where very few houses were observed. Unless there is population tension, muskrats generally do not seek out food which lies outside of their home range (Errington, 1963). Instead, they usually choose plants which are near their lodges even though these emergents may not have the highest nutritive value.

Although *Equisetum* contained large numbers of muskrat houses (per acre) in late fall, its low overall utilization relative to

other emergents might be attributed to sampling error. The smaller-sized sample plot used to obtain an index of use for *Equisetum* and the time the sample was run (September 16 - 21), probably did not allow a statistical detection of the late fall increase in *Equisetum* use.

Essentially two basic shoreline types were distinguishable on South Egg Lake. The shoreline characterized by the presence of emergents next to the willows (the willows, here, signifying the true shoreline) was 6.9 miles, while 0.9 miles of shoreline had very few or no emergents. There were three bank runs per 300 yards of emergent shoreline.

While *Phragmites* was singly the most utilized emergent on South Egg Lake, the value of the mixed shoreline species in summer should not be underestimated. Assuming that three muskrat runs per 300 yards of shoreline and three animals per run are accurate indices of the peripheral use of South Egg Lake, there would be 17.6 runs and approximately 55 muskrats per mile of shoreline emergents. Theoretically, this amounts to 380 muskrats along the entire length of emergent shoreline. On the basis of house counts (429 houses and 5.0 muskrats per house), a minimum estimate of the muskrat population of South Egg Lake in the fall was 2,145 animals. Therefore, the proportion of the total population utilizing the shoreline during the time that live-trapping samples were obtained was approximately 20 percent. It is assumed, here, that there were no bank dens since high water all but eliminated these structures.

No statistical information is supplied on quantitative food selection and consumption by the muskrats of South Egg Lake; however, one of the authors spent several hours in the late afternoons of summer and fall observing muskrats feeding. Versatility in food-getting appeared to be a regular phenomenon.

On two successive nights, four muskrats were seen returning to their houses in the *Phragmites* stand from adjacent stands of *Scirpus* and *Equisetum*. Examination of areas from which they had returned revealed an abundance of feeding sign. Freshly cut *Scirpus* and *Equisetum* stems were present in areas which had no houses.

On September 10, an adult muskrat (sex undetermined) was observed returning from a pure stand of *Scirpus* to its house on the shoreline, approximately 80-90 yards away. The muskrat was carrying a short stem of *Scirpus*, which it partially consumed upon arrival at the house. Shortly afterward, the muskrat again left the house and swam to a small, floating clump of *Typha* 10 yards away. Here it began feeding on lower portions of *Typha* stems.

During the trapping in habitat types, a number of feeding stations were observed in the *Scirpus* and mixed emergent sample areas. In some instances the nearest house was 200 to 300 yards away, indicating that muskrats had traveled considerable distances to feed.

Signs of feeding on all major emergent species of South Egg Lake (*Phragmites*, *Scirpus*, *Typha*, *Sparganium*, *Acorus*, and *Equisetum*)

were noted; however, freshly cut Typha and Scirpus stems were most frequently observed.

Habitat choice cannot be evaluated accurately without consideration of all biological, physical, and climatological factors. The reasons for differential selection of vegetation as food and housebuilding material can be only partially explained by preference. Other factors, including water regime, seasonal variation in climate, and their effect on muskrat behavior, are important, and have been considered in previous sections.

MANAGEMENT POTENTIAL

If one of the prime objectives of a management scheme for the Peace-Athabasca Delta is to maximize muskrat production, then man-controlled methods of habitat improvement will be necessary. It is evident that improvements could be made on the water-level regimes over that which occurred in recent years. If the use of dams, dikes, ditches, or pumps is determined to be feasible, both economically and from an engineering standpoint, a number of important measures could be implemented.

Ideally, a semi-stable water regime would offer optimum conditions for muskrat management. By semi-stable, it is implied that adequate water levels would be maintained for a period of 5 to 10 years, followed by a drawdown year to ensure that suitable acreages of emergent vegetation are regenerated. Because seedlings of emergent species such as *Scirpus*, *Typha*, *Acorus*, and *Sparganium* require exposed mud flats to germinate, the drawdown would have to be extreme. This would mean a severe reduction of the muskrat population in the low water year. In the following year, the marsh would be reflooded and muskrat numbers would presumably increase. In most lakes, an absolute minimum of 2.0 to 2.5 feet of water (except in the drawdown year) would be required to adequately sustain the muskrat population over winter.

Trapping can help maintain a healthy muskrat population. An adequate harvest will help minimize intraspecific competition thereby providing favorable breeding densities and more habitat

for rearing young. Regularly harvested areas will therefore produce high muskrat populations, year after year. Heavy trapping would also be helpful in thinning out the muskrat population in the spring preceding the drawdown.

It may be advisable to concentrate on specified areas on the Delta. The major portion of the muskrat population is concentrated on the Chipewyan Indian Reserve (subdivision F) and immediately west of the Reserve (subdivision B). Some of the lakes of these regions are characterized by dense, emergent shoreline cover consisting of favored muskrat food (_Typha_, _Scirpus_, etc.). However, most lakes are, or are in the process of becoming, shallow mud flats composed predominantly of grasses, sedge, _Equisetum_, and _Phragmites_. An increase in basin depth would considerably increase carrying capacity by providing winter access to shoreline plants and increasing shoreline length. In addition, a few of the lakes of the Reserve are deep enough to ensure that a suitable portion of the muskrat population will survive a drawdown year.

SUMMARY AND CONCLUSIONS

1. A one-year study of the muskrat on the Peace-Athabasca Delta was conducted from March, 1971, to March, 1972. The primary objective of the study was to determine the effect of low water levels on the population dynamics of the species.

2. South Egg Lake, the major study area, was live-trapped intensively in the summer. The young to adult female ratio was 12.5:1; the ratio of juvenile males to juvenile females was 2.5:1; and the adult male to adult female ratio was 1.3:1. The average litter size was 6.2.

3. Two litters were produced on South Egg Lake in contrast to three litters which were reported on North Egg Lake.

4. Summer live-trapping and early winter kill-trapping yielded an average of five muskrats per house and three muskrats per run.

5. House counts by ground and aerial reconnaissance indicated that the fall, 1971, muskrat population numbered approximately 40,000 animals: 15,340 in the Alberta portion, 13,070 on the Chipewyan Reserve, and 10,575 in Wood Buffalo National Park. Highest concentrations were in the Reserve area.

6. Fall muskrat densities ranged from 0.1 muskrats per acre of emergent vegetation, in subdivision I, to 11.4 muskrats per acre of emergent vegetation in subdivision B.

7. The most productive habitat in the summer on South Egg Lake was _Phragmites_ (12.5 muskrats/acre) followed by _Equisetum_ (7.5 muskrats/acre). In terms of overall use, _Phragmites_ was the most important, followed by the mixed emergent stand, _Equisetum_, and _Scirpus_.

8. The mixed emergent stand and _Scirpus_ were utilized to a greater degree in the fall.

9. Virtually all marsh plant species were eaten by muskrats.

10. Selection of habitat for house building was probably influenced more by vegetation density than water depth.

11. South Egg Lake was flooded in July, 1971. The short-term effects of high water were harmful to the muskrat population; however, the long-term effects are expected to be beneficial.

12. In the spring of 1971, 37 percent of the houses sampled on the Delta were considered to be active. In the spring of 1972, 55 percent were active.

13. There was a definite relationship between house activity and total water depth. The critical minimum depth for survival was calculated to be 2.5 feet in 1971 and 2.0 feet in 1972. The percentage of active houses increased as total depth increased.

14. The estimated winter survival of muskrats in 1971-72 was approximately 45 percent.

15. The potential breeding population for 1972 was 17,000 - 22,000 animals, of which more than 50 percent were removed by local trappers. The actual breeding population for 1972 is between 4,000 and 9,000 animals.

16. The fall, 1971, muskrat population reached one of its all-time lows. This is attributed to the recent low-water levels of the Delta.

17. Seventy-one percent of the lakes sampled did not have adequate water depths for optimum muskrat survival.

18. Spring predation was generally greater on the shallower lakes than on the deeper lakes.

19. The present low-water conditions of the Peace-Athabasca Delta necessitate man-controlled measures if the muskrat population is to be expected to reach its previous high numbers.

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The authors would like to express their sincere gratitude to the following people for their contributions toward this study: Gerry Townsend, for his guidance in project planning; Dennis Surrendi and Clint Jorgenson, who initiated the study and provided the groundwork for further investigations; C.W.S. technicians, Donald Holmes, Robert Ruttan, Brian Johnson, and Richard Salter, for their dedicated work in the field; local residents, Alec Courtoreille, Lloyd Flett, Benjamin Houle, Reg MacKay, Daniel Marcel, Joe Marcel, Isadore Voyager, Harvey Antoine, Roderick Fraser, and Joe Ratfat, whose knowledge of muskrats and field work proved invaluable; Arnie Goodman for his statistical assistance in data analysis; and David Westworth, who contributed valuable information from his own work.

Dennis Surrendi and Clint Jorgenson were responsible for compiling all data collected in spring, 1971. They presented their findings in a preliminary report entitled, "Some Aspects of Muskrat Winter Ecology on the Peace-Athabasca Delta," the results of which have been incorporated into this report.

Vernon Hawley and Dennis Surrendi devised a summer work plan which was initiated by Clint Jorgenson and Robert Ruttan in May, 1971, and continued by these authors in July, 1971. Donald Holmes' suggestions and criticisms of the foregoing paper were of utmost help.

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SECTION M

THE STATUS OF BISON ON THE PEACE-ATHABASCA DELTA

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INTRODUCTION

As a result of low water levels on the Peace-Athabasca Delta, coincident with initial impoundment behind W.A.C. Bennett Dam in 1967, concern was expressed about the effects on bison of the Delta. This study was initiated to determine: numbers and distribution of bison on the Delta, natality and mortality, food habits, habitat requirements, and the carrying capacity of the range, and to assess the effect of different water regimes on the above parameters.

Wood bison (*Bison bison athabascae*) have always been part of the biota of the Athabasca-Peace-Slave River area. Reports of the early explorers (Wuetherick, Vol. III Appendices) indicate that wood bison were found throughout the area in much smaller numbers than are present today. Wood Buffalo National Park was established in 1923 to prevent a slaughter similar to the one which occurred on the plains. At that time Graham (1923; cited in Fuller, 1966) estimated the park population at 1,500. In the mid-1920's, 6,673 plains bison (*Bison bison bison*) were released along the Slave River a few miles above Fitzgerald (Fig. 1). During the winter of 1925-26 about 400 bison crossed the Peace River and invaded the Quatre Fourches and Sweetgrass sections of the Delta. The Park was enlarged to its present size of 17,300 square miles to include these regions. Plains bison breed freely with the wood bison, and a hybrid population now inhabits the Delta.

The study area was restricted to bison range south of the Peace

River and east of Peace Point; that is, that area bounded by French Lake and the Birch River Delta on the west, including the south shore of Lake Claire, and extending east as far as the Embarras and Rochers Rivers (Fig. 1). Although the Lake One region is outside the Delta, bison south of the Peace move into and out of it. Therefore, it was included in the study. Dirschl (1970) gives a detailed description of the Delta area.

Fig. I Bison range (shaded area) in relation to Wood Buffalo National Park

METHODS

Because Wood Buffalo National Park supports the largest free-ranging population of bison in North America, there has been continued interest in their numbers. Data on bison in the Park have been collected intermittently during the past 50 years (Raup, 1930; Soper, 1941; Fuller, 1950, 1966; Roe, 1951; Novakowski, 1957, 1961a & b; McCourt, 1970; Kuyt, 1971). This study was limited to one year, and I have drawn heavily upon both published and unpublished reports to provide information on population growth rates, food habits, and other aspects.

Various methods of estimating the bison population have been attempted. The ground census was one of the earliest (Raup, 1930). Most ground counts were done along trails in the forest and animals had to be recorded before they disappeared into the trees (Fuller, 1966). Aerial surveys are more accurate but have limitations because bison in wooded areas are difficult to see. Several investigators found that herds stampeded if an airplane is flown lower than 1,000 feet; their surveys were done at higher altitudes (Fuller, 1950, 1966; Novakowski, 1957; McCourt, 1970; Kuyt, 1971). Winter counts were considered to be more accurate than summer ones because of the contrast in color between animals and snow, and because trails and feeding areas could be spotted more easily in snow (Soper, 1941). Transects were used until Novakowski (1961a) compared results from transect and total count methods and found 2,000 more animals on the Delta using the total count system than he had estimated from transects. Subsequently, only the total count method has

been used (McCourt, 1970; Kuyt, 1971).

For this study, counts were done in July, September, and December, 1971, and March, 1972. Summer and fall counts employed a Piper Super Cub. For winter counts we used a Cessna 180. All surveys were done at an altitude of 800 feet above ground level.

We consider the March survey to be the most accurate one because it sampled some areas not usually flown (e.g., between French Lake and Lake One; Lake One and Sweetgrass), because the sighting conditions were excellent, and because bison were out in the open during warm weather.

Adult:calf ratios were determined using an aerial photography technique (McCourt, 1970). During July, 1971, we photographed several herds using Hasselblad cameras mounted in a Piper Apache. Calves were reddish and were distinguished from adults by color differences.

Mortality was estimated from information supplied by residents of Fort Chipewyan, known deaths, and by comparison of population estimates.

Carrying capacity of the Delta was assessed by examining utilization of plants by bison after winter and before new growth obscured the old.

POPULATION

Soper (1934; cited in Fuller, 1966) was the first person to estimate the bison population in Wood Buffalo National Park after the plains bison had become established. He concluded that 10,000 to 12,000 bison were present. In 1949 the Park population was estimated at 12,000 to 15,000 (Fuller, 1966).

The earliest estimate of the Delta population was by extrapolation from a Park survey done by Novakowski (1957) (Table 1). Twenty-five percent of the area was covered and the count was multiplied by four to get 7,600. In 1961, the population was estimated at 8,050 (Novakowski, 1961a).

The average summer count in 1970 was 5,307 non-calves. By adding his calf estimate, McCourt determined that 7,300 to 7,900 bison used the Delta as summer range (Table 1). Surveys were continued during winter 1970-71 (Kuyt, 1971) and a maximum number of 8,744 animals were seen (Table 1).

In July, 1971, I counted 7,792 non-calves on the Delta and estimated that with 17 percent calves, 9,500 to 10,000 bison occupied the Delta summer range. Further counts in fall and winter, 1971-72, indicate that approximately 9,500 bison now inhabit the Delta (Table 1).

Although the data are fragmentary, it appears that the number of bison on the Delta increased to a level of about 8,000 and remained fairly stable around that figure until winter, 1971. At that time, there was an abrupt increase of approximately 1,000

Table 1. Aerial counts of bison on the Peace-Athabasca Delta.

Date	Investigator	Bison Counts on Delta	
1934	Soper (1941)	10,000 - 12,000[1]	
1949	Fuller (1950)	12,000 - 15,000[1]	
Feb-Mar/1957	Novakowski (1957)	12,000 - 14,000[1]	
Feb-Mar/1957	Novakowski (1957)	7,626	
February/1961	Novakowski (1961)	6,800	
February/1961	Novakowski (1961)	8,050	
June 24/1970	McCourt (1970)	4,037[2]	
June 27/1970	McCourt (1970)	5,885[2]	
July 2/1970	McCourt (1970)	5,693[2]	
July 8/1970	McCourt (1970)	5,019[2]	Total: 7,300-7,900
July 15/1970	McCourt (1970)	5,959[2]	
July 22/1970	McCourt (1970)	5,457[2]	
July 28/1970	McCourt (1970)	4,848[2]	
August 5/1970	McCourt (1970)	4,949[2]	
August 12/1970	McCourt (1970)	5,613[2]	
August 22/1970	McCourt (1970)	5,606[2]	
December 8/1970	Kuyt (1971)	6,070	
January 20/1971	Kuyt (1971)	8,275	
February 3/1971	Kuyt (1971)	8,253	
February 18/1971	Kuyt (1971)	8,205	
March 4/1971	Kuyt (1971)	7,754	
March 25/1971	Kuyt (1971)	8,744	
July 10/1971	Allison (1971)	7,792[2]	Total: 9,500-10,000
September/1971	Allison (1971)	6,779	
December/1971	Allison (1971)	7,099	
March/1972	Allison (1972)	9,263	

[1]Estimates of total population in Wood Buffalo Park.

[2]Counts of non-calves only.

animals to 9,000. By July, 1971, the number had risen to between 9,500 and 10,000; in March, 1972, it was about 9,500. The increase is probably partly a result of a net movement of bison scuth across the Peace River during the winter of 1970-71 and partly of good calf survival in 1971.

Unexplained movements of animals across the Peace have apparently occurred in previous years and may involve 800 to 900 animals (Stevens, 1954). This may be an occasional but irregular occurrence. Soper (1941) probably observed the same phenomenon when he states that animals resident on the Sweetgrass meadows stay there year-round, and that the bison appearing in the Egg Lake region each winter come from north of the Peace River. Subsequently, surveys from the air have indicated the migration pattern outlined below.

NATALITY AND MORTALITY

The actual number of births in any population of wild animals can only be estimated. Data gathered from reproductive tracts indicate the potential production, and adult:calf ratios provide a measure of actual population increment _at the time they are taken_.

Reproductive tracts of bison were collected during the annual slaughters during 1952 to 1959. Pregnancy rates varied from 42 percent in 1959 to a high of 76 percent in 1952 (Table 2). Assuming that all pregnancies were successful and the sex ratio of the population was 1:1 (Fuller, 1966), we would find a herd ratio of 100 adults : 30 calves, or 23 percent calves.

Delta herds in previous years contained approximately 20 percent calves (Novakowski, 1957; Currier, 1971). From photographs taken in July, 1971, we obtained an average of 17 percent calves. Periodic counts made during past summers provide an index of reproductive success and rate of calf mortality during the summer (Table 3). In 1970, for example, percentage of calves in the population decreased from 25 percent in July to 18 percent in August (McCourt, 1970). Similarly in 1951, percentage of calves decreased from 23 percent in July to 12 percent by the following December (Fuller, 1966). Although there is considerable variation in calf ratios from year to year, Fuller's (1966) generalization seems to reflect the usual situation. He stated that a normal calf crop on the Sweetgrass meadows is 20 percent to 25 percent of the total population in

Table 2. Pregnancy rates of females in Sweetgrass herds.

A. Herds observed in 1952.[1]

Age Class	1	2	3	Young Adult	Adult	Aged	Total
Number in sample	11	17	31	42	9	6	116
Percent pregnant	9	59	81	86	77	33	76

[1]After Fuller, 1966.

B. Herds observed from 1957 to 1959.[1]

Year	1957			1958			1959		
	Number in Sample	Pregnancies		Number in Sample	Pregnancies		Number in Sample	Pregnancies	
Age Class		Number	Per Cent		Number	Per Cent		Number	Per Cent
1	9	0	0.0	12	0	0.0	8	0	0.0
2	39	11	28.0	31	20	64.5	37	10	27.0
3	34	17	50.0	35	26	74.2	40	13	32.5
4	25	18	72.0	26	21	80.0	24	11	45.8
5-6	33	23	70.0	17	13	76.4	36	21	58.3
(Adult) 7-10	45	28	62.0	19	11	61.0	69	33	49.3
(Old) 10	17	9	53.0	5	3	60.0	9	2	22.2
Total	202	106	54.8	145	94	70.6[2]	223	90	41.8

[1]After Choquette and Stewart, 1959.
[2]After deduction of the number of animals in the yearling class from the total.

Table 3. Proportions of calves in bison herds.

Date	Source	Area Surveyed	Type of Survey	Number of Calves	Total Number of Bison	Per Cent Calves of Total
February/1949	Fuller (1950)	W.B.N. Park	Aerial count	26	323	8.1
May 16/1951	Fuller (1966)	Lake Claire	Aerial count	68[1]	675	10
June 5/1951	Fuller (1966)	Lake Claire	Aerial count	138[1]	766	18
June 18/1951	Fuller (1966)	Lake Claire	Aerial count	194[1]	1,211	16
July 9/1951	Fuller (1966)	Lake Claire	Aerial count	208[1]	903	23
July 22/1951	Fuller (1966)	Lake Claire	Aerial count	124[1]	727	17
Sept. 24/1951	Fuller (1966)	Lake Claire	Aerial count	71[1]	376	19
Dec. 6/1951	Fuller (1966)	Lake Claire	Aerial count	22[1]	181	12
July 5/1956	Novakowski(1957)	W.B.N. Park	Aerial count	164	1,007	16.3
Sept. 8/1956	Novakowski(1957)	W.B.N. Park	Aerial count	56	296	18.9
Feb-Mar/1957	Novakowski(1957)	W.B.N. Park	Aerial count	55	308	17.9
July 22/1970	McCourt (1970)	P-A Delta	Aerial photos	359	1,432	25.1
July 28/1970	McCourt (1970)	P-A Delta	Aerial photos	106	546	19.4
August 12/1970	McCourt (1970)	P-A Delta	Aerial photos	161	892	18.0
February/1970	Currier	Sweetgrass	Vaccinations	800	3,921	20.4
June/1971	Currier	Sweetgrass	Vaccinations	168	947	17.7
July 12/1971	Allison	N. of Lake Claire	Aerial photos	307	1,846	16.7

[1] By calculation from Table 9 of Fuller (1966).

late June or early July and this decreases by about 2 percent per month until December. By the end of the year, then, there would be 10 percent to 15 percent calves.

Diseases of bison in Wood Buffalo National Park have received considerable attention. However, the bison mortality directly attributable to disease is difficult to estimate. Tuberculosis (caused by *Mycobacterium tuberculosis*) and brucellosis (*Brucellosis abortus*) are the most common diseases but outbreaks of anthrax also occur.

Tuberculosis was first reported in the Wainwright herd by Cameron (1923; cited in Choquette et al., 1961), and it is generally believed that the disease originated in Wood Buffalo National Park with the introduction of plains bison from Wainwright (Fuller, 1966). The incidence of tuberculosis is lower at Sweetgrass than at Hay Camp (Fig. 1) because an inverse relationship exists between the incidence of tuberculosis and the distance of herds from the release site (Fuller, 1966). Some bison die from tuberculosis, and others, weakened by the disease, succumb to accidents or predators.

The incidence of brucellosis in Delta herds was 35 percent in 1957 and 45 percent in 1958. Brucellosis affects production by lowering the pregnancy rate in infected animals (Fuller, 1966).

In recent years, the National Park has attempted to control disease through an extensive vaccination program. The animals must be herded and confined until inoculated; consequently, this causes stress and some mortality to the herd. The mortality

varies yearly, and in 1972, approximately 100 animals succumbed during the program.

The timber wolf (Canis lupus) is the only known natural predator of bison on the Delta (Soper, 1941; Fuller, 1966). Wolves hunt by cutting a single animal from the herd and tend to prey on the very young, the very old, the diseased, and the crippled. Healthy, productive bison are seldom taken (Fuller, 1966). Black bears (Ursus americanus) are frequently seen near bison or feeding on carcasses. They may kill an occasional calf, but most of the bison they eat is carrion.

Another major cause of mortality in bison is drowning (Soper, 1941; Fuller, 1966). Most drownings occur during spring floods, but a few animals drown by falling through rotten ice before breakup. Severity of mortality from this cause probably is related to amount of Delta flooded, characteristics of the ice breakup (including timing), and yearly variations in migration of bison. An estimate of mortality from this cause in the early 1940's was 30 to 40 animals per year (Soper, 1941). After the spring floods of 1961, more than 1,100 carcasses were found (Campbell, Currier, pers. comm.), and estimates of total mortality from drowning were as high as 3,000 animals. In 1971 there were 48 known drownings on the Delta.

Humans have been a major predator on bison in Wood Buffalo National Park. A slaughterhouse was operated from 1954 to 1962 and since then bison have been harvested to provide meat for Fort Chipewyan residents. Although there was no legal harvest in

1972, some animals were taken by residents of Fort Chipewyan for food.

FOOD HABITS

Bison are primarily grazers and therefore find their food on the large open meadows of the Delta. There is considerable variance among authors about which particular species are most important for food. This may be explained in part by the fact that bison food habits were studied in different sections of the Park. Earlier studies indicated that sedges (*Carex* sp.) were preferred year-round (Raup, 1930; Jeffrey, 1959; Holsworth, 1960). Grasses (*Calamagrostis* sp.) were also found to be used (Jeffrey, 1959), and bison at times browsed on willows (*Salex* sp.) during the winter (Holsworth, 1960).

McCourt (1970) sampled vegetation in feeding areas near Sweetgrass to determine food habits. He found *Carex atherodes* constituted over 90 percent of the diet of bison and states that there are relatively few stands of *Calamagrostis* but that bison grazed the young stems. Reynolds (1970) analyzed 50 fecal samples collected by McCourt during the summer of 1970. His analysis concludes that the summer diet of bison is primarily sedges (82 percent *Carex atherodes* and 4 percent unidentified *Carex* sp.), with *Calamagrostis* sp. second in importance at 2.4 percent. He found forbs to comprise only .05 percent of the samples. Analysis of fecal samples collected during winter 1970-71 indicated the bison fed almost entirely on *Carex atherodes*.

During May, 1971, an area of known winter bison concentration just north of the Prairie River was observed to determine the extent of winter grazing. Here the sedge was eaten quite low but

had a fair carry-over. The long slough areas of _Equisetum_ sp. which were just emerging from the ground had been completely eaten. In other areas where bison were not as concentrated, only the tops of the plants were used. _Carex atherodes_ was the desired species. A lesser degree of use occurred on _Carex aquatilus_ and _Calamagrostis canadensis_ were less used, and occasional browsing of willcws occurred. The animals did not appear to have rooted to the crowns of the plants except in some solid stands of _Equisetum hyemale_ which were eaten off to ground level. Heavy concentrations of bison on some areas would suggest heavy use of the vegetation, but this was not borne out by observation except on drier sites of low productivity where the animals may be concentrating to obtain salty species.

CARRYING CAPACITY OF THE RANGE

Data from plots on the Slave River show an average of 1,500 pounds of dry matter per acre from a Carex aquatalis - Calamagrostis inexpansa wet meadow (Pringle, 1971). Using a figure of one-third carry-over for this type, there are approximately 1,000 pounds of usable forage per acre.

Even though Calamagrostis canadensis in pure stands shows very heavy production, it does not appear to be a preferred species and for this reason only 500 pounds per acre has been assigned to it (Table 4). Similarly, other vegetation types were rated on the basis of observation and previous knowledge. Acreages used were those available in subdivisions G, H, I, and J (Vegetation Mapping report).

In order to determine a probable carrying capacity for the Delta, the following assumptions were made:

(a) bison at present are using only preferred areas and do not range extensively outside the National Park.

(b) bison appear to exist on poorer quality vegetation than do range cattle, particularly in winter.

(c) it requires approximately 660 pounds of dry matter per month for maintenance and gain for range cattle averaging 1,000 pounds. If we assume that the average weight of bison is slightly more than 1,000 pounds, then a conservative estimate of utilization might be 1,000 pounds of dry matter per month.

Table 4. Carrying capacity of bison on the Peace-Athabasca Delta, 1971.

Vegetative Type	Acres	Usable Lbs./A	Total Forage Usable (Thousands of lbs.)
Carex atherodes	134,000	1,200	160,800
Calamagrostis	77,000	500	38,500
Wet sedge	27,000	1,000	27,000
Low shrub	191,000	500	95,500
Tall shrub	88,000	300	26,400
Deciduous	25,000	300	7,500
Immature fen	49,000	100	490
Total annual yield of usable forage			356,190,000 lbs.
Requirements per animal			12,000 lbs. per year
Carrying capacity (1971) based on usable forage			29,682 bison
Carrying capacity (1971) based on availability			19,788 bison
1971 herd on Delta			9,500 bison

(d) during winter (6 months) only one-third of the forage on the Delta is accessible to the bison because of snow, wind-drifting, and requirements for shelter.

The present carrying capacity is estimated at 19,800 animals (Table 4).

DISTRIBUTION, MIGRATION, AND HERD SIZE

Like the prairie buffalo, the bison of the Delta are migratory. Their migrations appear to involve most of the animals on the Delta.

Kuyt (1971) divided the bison range south of the Peace River into 10 convenient zones marked by geographical boundaries (Fig. 2). He charted the distribution of bison in each of these zones. McCourt's (1970) data has been tabulated according to this scheme (Table 5).

During late spring and summer, bison were concentrated in the Sweetgrass area north of Lake Claire (McCourt, 1970) where calving occurs. Occasional lone animals were found on the margins of Lake Claire. During late July and August, the bison began to move south and east toward Prairie River and Hilda Lake. By the peak of the rutting season (September) they had scattered throughout the entire wintering area, with highest numbers in the Quatre Fourches, Mamawi Lake, and Hilda Lake areas (Table 5, Fig. 3). During winter, local shifts occurred as the bison moved from large open meadows into sheltered sloughs. In early March, the bison began to move west through the Baril Lake and Quatre Fourches regions, and by late March or early April they again were concentrated in the Sweetgrass area (Fig. 3). In April, 1972, bison congregated near Sweetgrass. During spring floods in May, large herds of animals moved south into the meadows east of Lake Claire, returning to Sweetgrass in June. There is no other data on spring movements of bison, so it

Table 5. Seasonal distribution of bison on the Peace-Athabasca Delta.

Date	Source	Percent of Total Found in Each Zone									
		Rocher-Coupe	Coupe-Quatre Four-ches	N. of Baril Lake	Baril L. to Quatre Fourches	Mamawi-Hilda Lakes	Baril-Claire Rivers	Sweetgrass	Lake One	French Lake	Birch River Delta
		1	2	3	4	5	6	7	8	9	10
6/24/70	McCourt (1970)[1]	-	-	-	-	0	-	100.0	0	0	0
6/27/70	"	-	-	-	-	0	-	98.3	0	1.7	0
7/2/70	"	-	-	-	-	0	-	89.9	8.3	1.8	0
7/8/70	"	-	-	-	-	0	-	100.0	0	0	0
7/10/71	Allison	-	-	-	0.4	1.7	1.0	95.6	0.6	0	0.3
7/15/70	McCourt	-	-	-	-	7.5	-	84.4	5.1	1.5	1.4
7/22/70	"	-	-	-	-	0	-	100.0	0	0	0
7/28/70	"	-	-	-	-	21.5	-	73.5	2.9	1.5	1.1
8/5/70	"	-	-	-	-	16.1	-	89.9	0	0	0
8/12/70	"	-	-	-	-	22.9	-	77.0	0	0.1	0
8/22/70	"	-	-	-	-	23.3	-	75.8	0	0	0.9
9/71	"	3.0	1.0	2.1	10.1	51.7	3.1	25.4	2.7	0	0.9
12/8/70	Kuyt (1971)	0.6	10.4	10.3	31.8	1.9	5.2	39.5	0.3	-	-
12/71	Allison	2.4	15.3	13.5	18.9	28.3	6.2	12.6	0.9	-	0.6
1/20/71	Kuyt	0.4	14.0	10.7	18.9	16.3	3.7	35.8	0.3	-	-
2/3/71	"	0.5	13.9	17.9	9.4	17.5	8.3	32.2	0.4	-	-
2/18/71	"	3.6	16.9	8.5	9.9	14.9	9.0	36.9	0.3	-	-
2-3/71	Novakowski (1957)	5.9	8.1	19.3	9.4	15.3	15.1	13.4	10.2	1.3	2.0
3/4/71	Kuyt	7.9	7.7	5.5	18.9	17.1	6.6	36.1	0.2	-	-
3/72	Allison	10.0	10.7	7.9	10.7	12.3	8.9	37.5	0.5	0.1	0.13
3/25/71	Kuyt	0.8	13.6	1.2	0.8	13.4	1.4	64.9	0.2	0.2	3.5

[1] Data reworked from maps.
- Area not flown.
0 No bison seen.

1971-72 -- Severe winter - much snow.

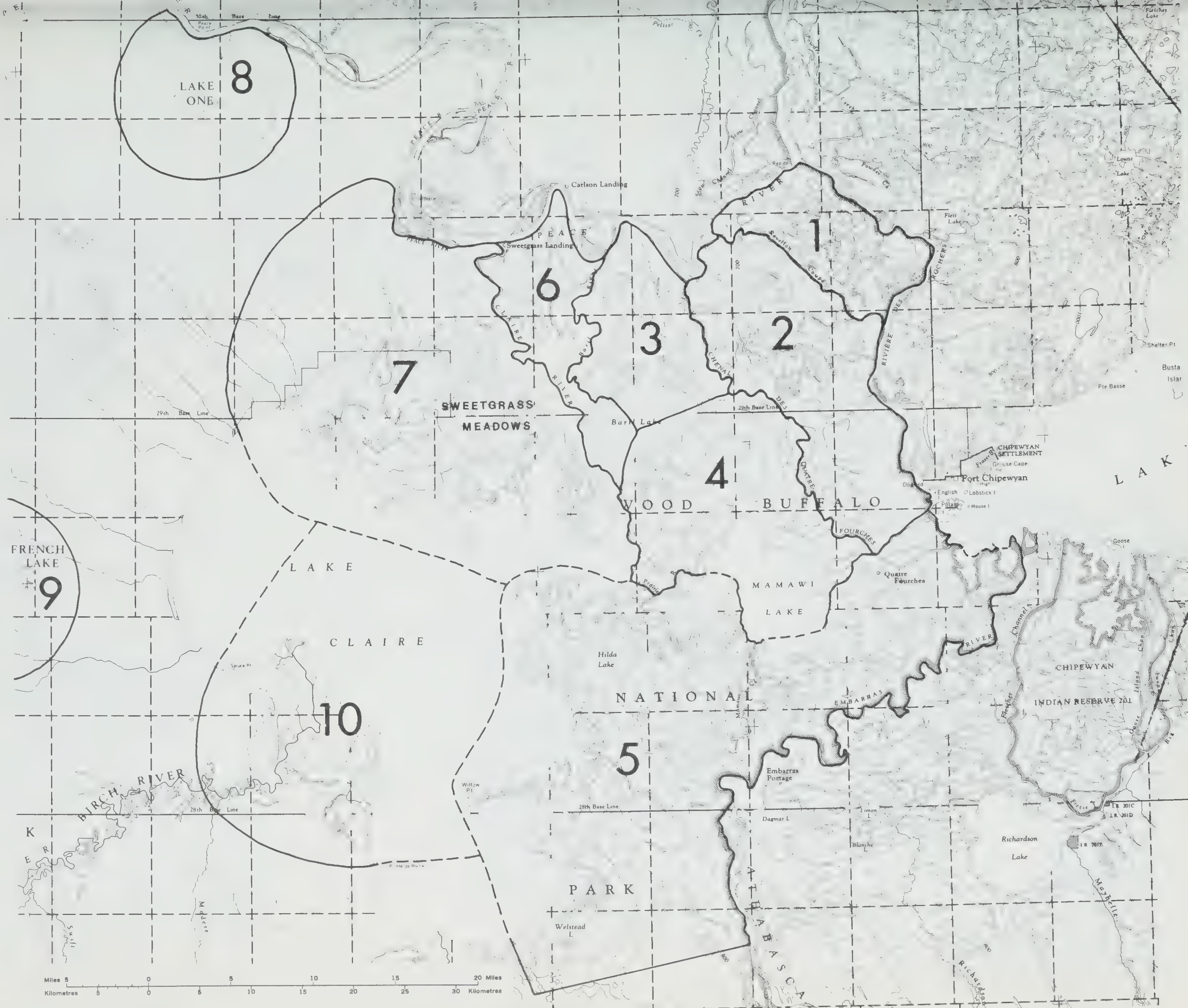

Fig. 2 Bison winter range on the Delta showing zones used in counts.

Fig. 3 Seasonal movements of bison on the Peace-Athabasca Delta.

is not known whether this is the usual pattern or if it was caused by high water.

Several investigators have recorded average aggregation sizes (Fuller, 1960; Egerton, 1962; McCourt, 1970; Kuyt, 1971). However, McCourt (pers. comm.) noted that results may not be comparable because each observer arbitrarily determines which animals comprise a herd. He assumed that bison within 100 or 200 yards of one another belonged to a common herd.

I found herds including up to 600 bison on the Sweetgrass meadows during the summer, and aggregations of 200 to 300 were common. When the bison began to disperse through their wintering ranges, they scattered, and even groups of 100 were rare until the end of the rut (November). Subsequent to the rut, larger aggregations re-formed, and groups of 100 or 200 were found in December. During January and February, the herds diminished again as the bison moved further into the forested parts of the Delta. Regrouping occurred with the first warm weather as the bison were moving toward the summer range. McCourt found the average herd size declined from 63 in late June to 26 in August. This study showed average sizes to continue to decline through September (Table 6), to increase between September and December, decline through February and increase again in early March (Kuyt, 1971; Table 6). There is evidence, however, of a tendency toward larger herds in winter than in summer north of the Peace River (Stevens, 1954).

Table 6. Size of herds of bison on the Peace-Athabasca Delta.

Date	Source	Average Number of Bison Per Herd
June 24/1970	McCourt (1970)	63.1
June 27/1970	"	58.3
July 2/1970	"	51.8
July 8/1970	"	34.6
July 10/1971	Allison (this study)	33.7
July 15/1970	McCourt (1970)	42.0
July 22/1970	"	42.6
July 28/1970	"	30.7
August 5/1970	"	37.5
August 12/1970	"	30.7
August 22/1970	"	25.7
September 11/1971	Allison (this study)	21.7
December 8/1970	Kuyt (1971)	46.3
December/1971	Allison	19.4
January 20/1971	Kuyt (1971)	41.8
February 3/1971	"	31.1
February 18/1971	"	34.0
March 4/1971	"	34.8
March/1972	Allison (this study)	22.1
March 25/1971	Kuyt (1971)	39.8

EFFECTS OF WATER LEVELS ON BISON

The effect of high water during flooding on mortality of bison has already been discussed. Under low water conditions that existed during 1970 and 1971 we did not see any immediate detrimental effects on numbers of bison. However, the bison range is a delicately balanced system dependent upon surface and ground water. The early effects of drying on the vegetation can be monitored (Dirschl's report) and the response of the bison to these changes can be predicted.

Initially, low water levels will provide more bison range. Drying and drawing back the water in many sloughs allows sedges to establish themselves, and I have noted that bison seem to feed in the newly exposed fen areas during summer. On a short-term basis, therefore, the low water levels have probably increased the available forage for bison. However, *Carex atherodes*, the most important year-round food of bison, requires a wet environment to thrive. The extensive *Carex* meadows at Sweetgrass are a seral stage in plant succession in this area and are maintained by periodic flooding and a high groundwater level. Invasion by drier land species has already begun and can be attributed to a lowered water table. During 1971, some sedges were observed to be dying, and grasses and willows were beginning to replace them. If the water levels were to remain low, the sequence of plant succession would continue and the bison range would diminish. Stable water levels would result in extensive sedge meadows being replaced by *Calamagrostis* with sedges being restricted to small borders about the edge of

ponds. This would eventually result in a carrying capacity considerably below what it is today.

ACKNOWLEDGEMENTS

Many people helped with this study, and I sincerely appreciate their assistance. D. Surrendi assisted in project planning, librarians B. Loveridge and S. Marpa helped me locate many unpublished reports, and C. Paley worked on technical aspects. I. Flett, R. Fraser, G. Lyster, Wood Buffalo National Park Area Supervisor, and G. Mason freely contributed knowledge gained from many years in the area, and R. Sinotte piloted the aircraft and acted as second observer. In addition, many other individuals helped with logistic support.

W. Pringle visited the Delta May 21 - May 24, 1971, to assess bison range and carrying capacity. His observations and conclusions on carrying capacity are included in this report.

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SECTION N

THE STATUS OF MOOSE ON THE PEACE-ATHABASCA DELTA

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ABSTRACT

Moose on the Peace-Athabasca Delta were studied from June, 1971, to June, 1972. Aerial surveying determined that moose are concentrated in regions that have an interspersion of habitat types including conifers or dense, tall willow as cover. The total population on the Delta is estimated to be 800 animals, or approximately one per square mile of suitable habitat. The sex ratio is 1:1, and the annual increment to the population is estimated at 20-25 percent. Major predators of moose are humans and wolves; the estimated annual hunter kill is 150 to 200.

Moose on the Delta are migratory, moving distances of more than 20 miles. Influxes of moose in early winter were noted in the McIvor River, Riviere des Rochers, and Dagmar Lake regions.

Browse studies indicate that much more food is available for moose than is being used. The Delta is divided into four classes on the basis of habitat type and optimum densities of moose assigned to each class. It is estimated that under intensive management the Delta could support approximately 5,500 moose.

Because there are few moose on the Delta and these are concentrated on high, more stable regions, water level changes of two or three feet will have little effect on moose populations.

INTRODUCTION

The moose (*Alces alces americana*) has played an important role in the Indian and Metis cultures of northern Alberta, both past and present. Historically, moose were present in the region of Fort Chipewyan and were a major food source for the early forts in the region (Wuetherick, 1972). There was no reference, however, to the extent they were hunted on the Peace-Athabasca Delta. According to residents of Fort Chipewyan, moose were so scarce on the Delta 40 years ago that even tracks were uncommon. It was not unusual for a man who saw a track to follow a single animal until he shot it - even if it took a week (S. Flett, F. Ladouceur, pers. comm.).

Since then the Indians and Metis have become concentrated within and near Fort Chipewyan. Moose continued to move into the Delta area and their numbers increased. Moose from the Delta area have now become economically important to the residents of Fort Chipewyan as a food source and the hides provide material for clothing and handicrafts. Therefore, when the Peace-Athabasca Task Force was established to study the effects of low water levels on the Delta, moose were among the species considered.

The objectives of this study were to determine:

(a) the population of moose on the Peace-Athabasca Delta;

(b) annual recruitment and mortality in the population;

(c) the distribution of moose on the Delta in summer and winter;

(d) the carrying capacity of the habitat with respect to food; and

(e) the effect of water level regimes on the population and moose habitat.

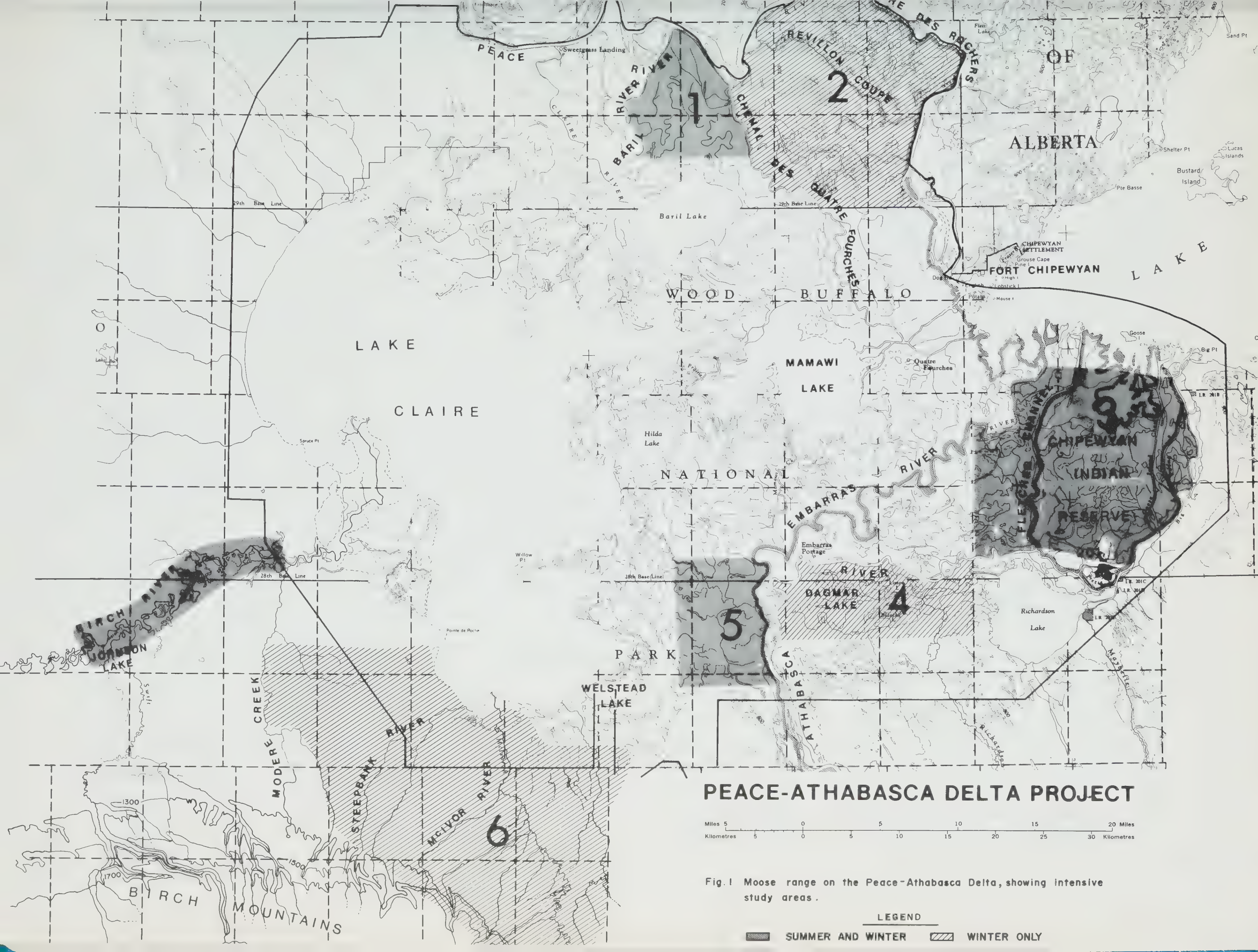
The study began in June, 1971, and continued until June, 1972.

DESCRIPTION OF STUDY AREA

The Peace-Athabasca Delta has been sculptured by water. Formed by the deposition of fine silt carried to the mouths of the Peace and Athabasca Rivers, the terrain is very flat. Major changes in relief are provided by outcrops of Precambrian rock and the levees along river channels or between lakes. Botanically, the Delta is an unstable region; the progression of plant succession is inhibited by the fluctuating water levels and fire. The climax white spruce forest occurs only on higher levees and older, protected parts of the Delta.

Because moose are mobile animals and inhabit forested, upland areas on the Delta, regions peripheral to the Delta proper were included in this study. The boundaries were the Peace River on the north; the Rochers River, Lake Athabasca, Steamboat Channel, and Richardson Lake to the east; the beginning of the Precambrian Shield and the south shore of Lake Claire to the south; and an imaginary line about 18 miles west of the west shore of Lake Claire (Fig. 1). In the fall, when it appeared that the moose may be migratory, the study area was extended south to the Birch Mountains. Dirschl (1970) gives a detailed description of the Delta area.

The study area comes under the jurisdiction of three separate agencies. The largest segment is part of Wood Buffalo National Park. Approximately 500 Cree and Metis have traditional hunting and trapping rights in the Park and they can legally shoot moose of any age or either sex throughout the year. The Chipewyan



PEACE-ATHABASCA DELTA PROJECT

Fig. 1 Moose range on the Peace-Athabasca Delta, showing intensive study areas.

Indian Reserve is administered by the Chipewyan Chief and Band Council. Members of the band may shoot moose within its boundaries any time of year. The remaining strip of Delta is administered by the Province of Alberta. Hunting is limited to a fall season in this region with no age or sex restrictions. However, treaty Indians (Cree or Chipewyan) may legally shoot moose in Alberta throughout the year. (In practice, however, these distinctions are blurred; in general, anyone who spots a moose shoots it regardless of jurisdiction or legality.)

The boundaries between separate jurisdictions are either rivers or lakes. They may provide some barrier to movement during the summer, but when rivers are frozen (November to April), the moose can move freely from one area to another.

METHODS

During the summer, reconnaissance surveying for moose was done over the entire Delta in a Piper Super Cub aircraft. Three high-density areas were located (Fig. 1: 1,3, and 5) and searched intensively at low altitude, using closely spaced transects in an attempt to arrive at a density figure. A wider pattern was used to sample other areas of suitable moose habitat on the Delta.

Intensive surveys continued in the winter. Seven areas, including the three summer segments (Fig. 1), were each surveyed several times to determine changes in distribution over the winter.

Using the habitat classifications, water, open meadow, low willow, tall willow, deciduous trees, and conifers, the observers recorded the vegetation type where each moose was observed and up to 200 yards away, if different.

All moose sighted prior to October 30 were classified as bull, cow, or calf. No attempt was made to identify yearlings because the observers felt it would not be accurate. Bulls began to drop their antlers in December and calves were large enough that they could not be distinguished from the air unless they stood beside an adult, so this classification was discontinued during the winter. Mortality was estimated from information provided by residents of Fort Chipewyan and by extrapolation from known kills.

Food habits of moose on the Delta were determined by:

(a) collection of 10 rumen samples from hunter-killed moose in late summer,

(b) incidental observations of feeding moose in summer,

(c) a browse survey carried out during the summer of 1971 to study the feeding of moose during the winter of 1970-71, and

(d) a browse reconnaissance done by Edmund Telfer during March, 1972.

Rumen samples were preserved with a 10 percent formalin solution. All samples were washed through screens having mesh sizes of 8 and 16. Most pieces which washed through the number 8 mesh were too small to identify. All identifiable material was classified to family, and, where possible, to genus and species.

The quantity of each species in the sample was expressed as percentage total dry weight. Small samples of dried material were stored in vials for future reference.

Twenty-one sites were chosen for 1971 summer browse surveys, seven in each of the three areas of summer moose concentrations (Fig. 1: 1, 3, and 5). Each sample plot was a 30 meter square located 50 paces north of the spot chosen. Species, height, and cover of shrubs, bushes, and trees were recorded along the diagonal of the square (length - 43m). Ten to 25 stems of each species noted on the transect were chosen within the sample

plot. On each stem, the percentage of twigs browsed by moose was estimated for height classes, 0-0.5 m, 0.5-1.0 m, 1.0-2.0 m, and over 2.0 m. All evidence of moose use was classified as summer or winter.

The browse reconnaissance was carried out during the week of March 21-25, 1972. An overview of the entire area was obtained using a Cessna 180. A helicopter was used to assess browse conditions in the McIvor River area, near the Birch Mountains, and northwest of Welstead Lake. An additional two days were spent on the ground in the Sweetgrass, Baril Lake, and Quatre Fourches regions.

POPULATION AND DISTRIBUTION

Moose range on the Delta was rated as prime, good, moderate, or poor on the basis of summer sightings (Fig. 2). The prime areas were characterized by the establishment of large stands of white spruce (*Picea glauca*). Numerous small channels, lakes, or oxbow lakes were interspersed with balsam poplar (*Populus balsamifera*), aspen poplar (*P. tremuloides*) or birch (*Betula papyrifera*), and willow (*Salix* sp.). The understory consisted of several species of shrubs. A second type of prime summer habitat consisted of the younger, lower, and more frequently flooded areas characterized by many lakes and channels, open meadows, low willow and thick, tall willow.

Good habitat for moose included areas of white or black spruce (*Picea mariana*) interspersed with open muskeg, and Precambrian outcrop areas.

Moderate moose habitat in summer consisted of areas where very few moose were seen or reported, usually open jackpine forest, or muskeg with scrub spruce.

Poor habitat consisted of areas which were unsuitable for moose. These were primarily large open meadows of sedges or grasses (Fig. 2).

The observers felt that many moose were missed during the summer because of the heavy canopy of leaves in most regions. Therefore, density data were not calculated.

At the onset of winter, moose were much more readily seen, and

density data could be calculated. Densities varied between 5.1 and .05 moose per square mile in wooded areas (Table 1). Some regions considered to be prime range in summer still supported relatively large numbers of moose; however, in early winter very few were seen on the Welstead study area, or along the Birch River.

During November, very high concentrations of moose were seen on the willow flats north of the mouth of the Steepbank River and along the edges of the Birch Mountains. A survey of the entire McIvor River study area (Fig. 1) in December revealed concentrations of more than 1.5 moose per square mile. Most of the observations were recorded in the west end. At this time, no moose were sighted in either the Birch River or Welstead Lake areas. In January, surveys of the three regions were again carried out. A few moose reappeared in the Birch River and Welstead Lake study areas. Moose in the McIvor River region tended to be concentrated to the east, with many animals sighted just south of Welstead Lake. Some animals, however, remained on the Steepbank Flats with more sightings between there and the Birch River than previously. High concentrations were also noted in a small area near Sweetgrass Landing (Fig. 3).

By late February, the moose had left the Steepbank Flats and were scattered throughout the McIvor Region in densities of less than one per square mile. Both the Birch and Welstead areas had more moose sightings and sign than previously noted. Densities in each of the remaining study areas (Baril Lake, Rochers River, Dagmar Lake, and the Chipewyan reserve) remained fairly constant

Fig. 2 Habitat rating of moose summer range on the Peace-Athabasca Delta based on moose sightings.

Table 1. Moose numbers and densities in winter.

Study Area	Number of Moose*	Number Sq.Mi.	Moose/Sq.Mi.	Total Sq.Mi. Habitat*	Total Moose	Estimate
Baril Lake	28	45	.62	Nov-Dec 110, Jan 78	69 49	
Welstead Lake	Nov-Dec 3, Jan 11	57	Nov-Dec .05, Jan .19	89 121	4 17	
Chipewyan Reserve	23	167	.14	236	33	
Dagmar Lake	17	60	.28	79	22	
Rocher-Quatre Fourches	15	148	.10	148	15	
McIvor River area	216	160	1.35	160	216	50% observed
Birch River	2	25	.08	25	2	399 x 2=800
Carlsons Point area	25	11	2.3	11	25	800
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Total				858	399	800 =.93 moose/sq.mi.
High Density Areas						
Carlsons Point	25	11	2.3			
Steepbank River Flats	39	6.4	5.1			
Modere Creek to Steepbank R.	87	49	1.8			

* Numbers of moose are averages of all winter counts unless otherwise stated.

throughout the winter (Table 1). Reconnaissance surveys over both the Rochers and Dagmar regions during the summer turned up no moose, and few casual sightings were reported in these regions.

The Delta was classified for winter use as prime (areas of moose concentration), poor (few sightings - areas in which few animals were seen or from which moose migrated), or poor on the basis of actual moose densities observed (Table 1; Fig. 3). The potential of the habitat to support moose was not considered and the rating is a comparative one for the Delta only.

Aerial surveys, although limited in accuracy and usefulness, are still the best way of assessing big game populations over a large area. Bergerund and Manuel (1969) and Evans et al. (1966) discuss methods and limitations of this technique for moose. It must be kept in mind that numbers and densities produced from aerial survey data are only minimum figures. How closely these figures approach the real situation depends on several variables: weather during the survey, survey method used, observers' accuracy and experience, observer fatigue, type of terrain covered, and habitat type. It is numerically impossible to assess the effect of some of these variables. However, LeResche and Rauch (in press) tested the effect of observers' experience, snow conditions, and habitat type on the precision of moose counts over one-square-mile enclosures containing known numbers of moose. Experienced counters, when surveying in aircraft in excellent conditions, saw a mean of 68 percent of the moose. A higher proportion of moose were seen in pens with

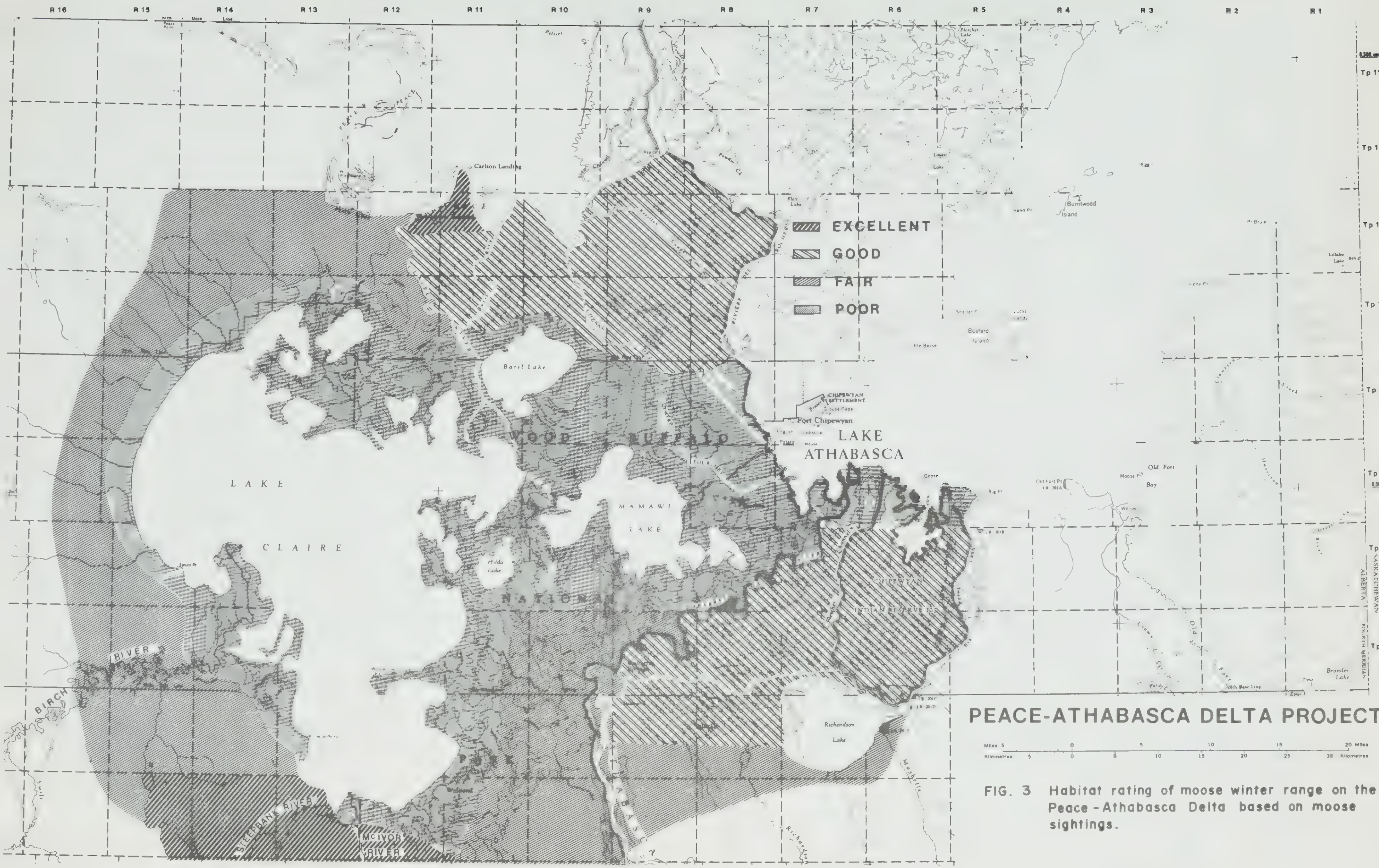

FIG. 3 Habitat rating of moose winter range on the Peace-Athabasca Delta based on moose sightings.

flat terrain and little mature timber. In this study, all surveys between June and January employed the author and the pilot as observers. After late January, different pilots and, sometimes, second observers were used. Most moose were seen in wooded terrain. Therefore, I felt confident that, on the average, we saw no more than 50 percent of the moose present. The total calculated number of moose from density figures was multiplied by two to give an estimated population of 800 animals occupying 858 square miles of habitat (0.9 moose per square mile, Table 1). This is a very low figure; on the Kenai Peninsula in Alaska normal winter densities are 15 moose per square mile (LeResche and Davis, 1971).

MIGRATION AND MOVEMENTS

Many moose remain in a relatively small and well-defined home range all year; however, others are migratory (Edwards and Ritchey, 1956; LeResche and Davis, 1971). Although the data from the Peace-Athabasca Delta are fragmentary, it appears that some of the animals are stationary year-round and others move at least 20 miles. Moose were present winter and summer in two major summer areas (Baril Lake and the Chipewyan Reserve). Moose apparently moved out of the Welstead and Birch regions since the McIvor River area was invaded by large numbers of moose during early winter. The Rochers River region and the Dagmar Lake area, some of which has been burned, also appeared to have an influx of moose in winter. Gradual changes in distribution lead me to believe that the moose from the Welstead and Birch River regions move south into the McIvor area for the early winter and those from the Baril region move tc Sweetgrass Landing. The Rochers and Dagmar moose may come from the Baril and Reserve areas respectively. A tagging program cculd provide definitive information.

SEX AND AGE RATIOS, NATALITY AND MORTALITY

Sex and age ratics obtained in the summer and fall were very similar. In summer (n=138) there were 100 cows:90 bulls, and 100 cows:44 calves. In the fall, there were 100 cows:105 bulls, and 100 cows:46 calves (n=122).

Sex ratios on the Delta approximate 1:1. The slightly higher proportion of males observed during the fall can probably be accounted for by a relatively small sample size, the difficulty in sighting antlers early in the summer, and the tendency of bulls to travel more widely than females during the rut. This balanced ratio is maintained by unselective hunting. Except for having a slight predilection toward shooting calves or cows with calves, hunters probably are non-selective. Calves accounted for 18.8 percent of the population in the summer and 18.3 percent in the fall. The summer figure is probably low because calves may lie in the bush and not be spotted. Knowlton (1960) also noted that the calf component may appear to be even higher in winter than summer because of changes in activity pattern. However, the figures do indicate that calf mortality during summer is low. Total annual increment is probably 20-25 percent.

Human hunters and wolves are the major predators of large game animals on the Delta. Estimates of local hunters and known kills indicate that approximately 150 moose are taken annually by residents of Fort Chipewyan.

Wolves are not as able killers as men with rifles but do kill some moose. Most sightings of wolves occurred near bison

concentrations, but some animals in the far southern part of the study area probably depend entirely on moose as food. With an estimated population of 800 animals, an annual mortality of 200-250 moose of all ages would probably be sufficient to keep the population at its present low level.

POPULATION REGULATION

It is evident from the above discussion that the number of moose on the Peace-Athabasca Delta is far below the level which available food sources could support, although a one-year study was not sufficient to determine the dynamics of the population.

Because the pressure from hunters is both heavy and constant, few moose are found in suitable habitat close to or accessible from Fort Chipewyan, particularly during the summer. Local hunters are more opportunistic, persistent, and skilled than the average sport hunter. Dasman (1964) pointed out that subsistence hunting could lead to local extinction of a species, and this may explain the scarcity of moose on the Delta even 40 years ago. In Fort Chipewyan, a successful moose hunter still gains a great deal of prestige. However, since welfare is available, a very low moose population would probably suffer only from opportunistic hunting (i.e., a man carrying his rifle in his skiff sees a moose crossing a river) and the population would not be extinguished. Nevertheless, the pressure of hunting is one factor keeping the population at its present low level.

Much has been said but little written about the effect of interactions between moose and bison. Holsworth (1960) suggests that moose in Elk Island National Park will move elsewhere when confronted by bison. Residents of Fort Chipewyan (L. Flett, R. McKay, F. Ladouceur, pers. comm.) state that moose move out of an area when either bison or caribou move in. They claim that the moose, usually a relatively solitary animal, is disturbed by

the noise. Aerial survey data did indicate that as the bison moved north into the small sloughs and open meadows of the forest, the moose tended to be concentrated even further north. Some even moved across the ice to islands in the Peace River. This competition with bison for space could help keep the moose population low.

During the flood of the Athabasca River in July, 1971, much of the Chipewyan Reserve and Alberta section of the Delta were flooded. The moose seemed to move out of wet areas onto higher dry land even though the water was only two to four inches deep in many places. The Dagmar Lake study area was flooded all summer and only two moose were sighted. In high water years, then, large areas of suitable moose habitat may be unavailable during summer, forcing an exodus of resident animals.

FOOD HABITS

Analysis of rumen samples is the best way we have of determining the diet of moose, other than by direct observation of feeding animals. However, this method does have drawbacks. For instance, coarse woody material may be harder to digest and may stay in the rumen longer than non-woody plants. Consequently, fibrous plants may form a larger component of rumen sample than of the moose's actual diet.

During the summer, moose on the Delta ate primarily the leaves and twigs of browse plants (97 percent of material identified, Table 2). Willow was the main food (73.5 percent), followed by balsam poplar, birch, and aspen poplar (Table 2). Grasses, sedges, and other ground vegetation were used only slightly, accounting for 2.22 percent of the identified sample. Aquatic plants composed only 0.3 percent of the sample, even though a large proportion of summer sightings were of moose in water. During 1971, browse surveys were concentrated in those areas known to support concentrations of moose in summer. In all cases the impact of moose on browse was low (Table 3).

In all three study areas (Baril Lake, Welstead Lake, and the Chipewyan Reserve), the bulk of the moose's diet consisted of willow species and red osier dogwood (*Cornus stolonifera*). These two plants were also the most common ones in each area (Table 3: a and e).

The Welstead Lake and Baril Lake study areas are very similar in plant growth forms and successional stages. In each case the

Table 2. Summer food habits of moose.

Species Found in Rumen Samples		% Identifiable Material (dry weight)
Betula papyrifera	leaves	1.30
	stems	1.20
Cornus stolonifera	leaves	0.40
	stems	0.20
Picea glauca		0.40
Pinus banksiana		0.20
Populus balsamifera	leaves	5.50
Populus tremuloides	leaves	0.90
	stems	1.60
Salix sp.	leaves	19.10
	stems	54.40
Unknown leaf pieces		0.40
Unknown stem pieces		11.80
	Total % Browse Plants	97.40
Chamaedaphne calyculata		0.04
Cyperaecae (Fam.)		0.04
Gramineae (Fam.)		0.02
Heracleum lanatum		0.60
Leguminosae (Fam.)		0.20
Lycopodium complanatum		trace
Myriophyllum sp.		0.07
Potomageton richardsonii		0.20
Solidago canadensis		1.30
Typha sp.		0.02
Unknown seeds		0.80
Unknown buds		0.30
Unknown flowers		0.09
Parasites		trace
	TOTAL	100.5

Average percent of sample identified - 28%

Table 3. Use of browse by moose during winter 1970-71.

Study Area		Avail (a)	% Plants (b)	% Browse (c)	Total % Browsed (d)	Avail x % Total Use (e)	% in Diet (f)	Avail Index (g)	Use Index (h)	Pref. Rating (i)
Baril Lake (7 plots)	Amelancher alnifolia	8.1	50	50	25	202.5	5.8	2	5	2.5
	Betula papyrifera	12.6	12	5	6	75.6	2.2	3	2	.67
	Cornus stolonifera	84.5	73	30	22	1859.0	52.9	6	4	.67
	Populus balsamifera	0.5	40	20	30	15	.5	1	6	6.0
	Salix spp.	72.8	33	50	16.5	1201.2	34.2	5	3	.6
	Viburnum edule	32.5	26	20	5	162.5	5	4	1	.25
	Total	215.5				3515				
Welstead Lake (7 plots)	Amelancher alnifolia	<1	80	100	80	tr.	-	1	7	7.0
	Betula papyrifera	11.3	17	75	13	146.9	27.2	3	6	2.0
	Cornus stolonifera	38.4	25	20	5	192	35.6	6	4	.67
	Populus balsamifera	4.8	17	50	9	43.2	8	2	5	2.5
	Rubis sp.	15.2	3	10	.3	4.6	0.9	5	1	.20
	Salix spp.	61.8	12	18	2.2	136	25.2	7	3	.43
	Viburnum edule	14.2	4	30	1.2	17.4	3.2	4	2	.5
	Total	145.7				540.1				

(Continued on next page.)

Table 3. Continued.

Study Area		Avail (a)	% Plants (b)	% Browse (c)	Total % Browsed (d)	Avail x % Total Use (e)	% in Diet (f)	Avail Index (g)	Use Index (h)	Pref. Rating (i)
Chipewyan Reserve (7 plots)	Cornus stolonifera	9.0	25	30	8	72	11.1	2	2	1.0
	Populus balsamifera	<1	40	40	16	tr.	-	1	3	3.0
	Salix spp.	191	16	25	4	573	88.9	3	1	.33
	Total	200				645				

Footnotes. All calculations are done separately for each study area.

(a) Avail - Availability of species browsed by moose. This figure is calculated by adding the feet of canopy on transects on all 7 plots up to 3 m.
(b) % Plants - Percentage of stems which show winter use by moose.
(c) % Browsed - Percentage of branches browsed on plants showing use.
(d) Total % Browsed - Calculated by multiplying previous two categories.
(e) Avail x % Total Use - This is a figure which gives a relative idea of the moose's actual diet.
(f) % in Diet - Previous column expressed as a percentage for each area.
(g) Avail Index - All species browsed in each area are ranked, lowest receiving a rank of 1.0.
(h) Use Index - All species are ranked according to total use, lowest receiving a rank of 1.0.
(i) Preference Rating - Use rank divided by availability rank. A rank greater than one indicates that this species is used in higher proportions than it is available. A rank of less than one indicates that the species is available in higher proportions than it is used.

overstory is poplar and spruce. Birch is more common in the Welstead region and provides a considerable portion of the diet of moose in that area (Table 3: a and e). The Chipewyan Reserve has an overstory consisting almost entirely of tall willow and containing only three browse species (Table 3).

Studies of availability and use of browse species (shrubs and bushes up to three m. in height for moose) can be used to produce an index of use in a particular habitat.

Because the results for each study are based on an equal number of plots, the availability figures are directly comparable. Equivalent amounts of browse are available on the Baril Lake and Chipewyan Reserve areas, but the Welstead region offers only about two thirds as much (Table 3). Furthermore, more than five times as much browse was used on the Baril area as in any other region (Table 3).

Browsing removes the terminal bud on a branch and stimulates the development of lateral buds. Heavily browsed shrubs therefore develop a bushy or "hedged" appearance and remain low. Hedging was evident on a few red osier dogwood stems only in the Baril area. In the Welstead segment, some dogwood patches reached heights of four meters and were untouched by moose.

Species which were palatable to moose but uncommon on the study plots were browsed at levels higher than their relative density (Table 3). Serviceberry or Saskatoon (*Amelanchier alnifolia*), and balsam poplar stems were browsed heavily when they occurred. Lowbush cranberry (*Viburnum edule*) and raspberry (*Rubis* sp.)

were used sparingly by moose (Table 3). Alberta rose (Rosa acicularis) and alder (Alnus tenuifolia) were eaten only by hares.

Browse reconnaissance was carried out over a wider area in March of 1972. The Steepbank River (mouth) winter concentration area was very heavily browsed. Numbers of dead twigs indicated that both willow and birch also had been heavily used in previous years. Stands of birch and balsam poplar, about 30 years old, covered the hills on the edge of the Birch Mountains. Some severely hedged red osier dogwood was present in the understory.

Moose on the Delta feed primarily on willow, red osier dogwood, birch, and balsam poplar during the winter. In contrast, Alaskan moose (LeResche and Davis, 1971) use birch and cranberry (here Vaccinium vitis-idaea) with only three percent of their diet being willow. Moose on the Kenai Peninsula have much less snow to cope with than do moose on the Delta, and very low species are unavailable to the Delta population all winter. Red osier dogwood is used heavily throughout the range of moose wherever it occurs (Peterson, 1955).

Like many other animals, moose require a diversity of habitat types within their home range. Because a relatively small area must supply food and shelter for each animal, an interspersion of habitat types is required. Moose on the Delta, since they are at such low densities, can select and inhabit optimum regions. Such regions offer a mixture of coniferous, deciduous, and tall dense shrub stands for shelter, with low shrubland for forage. A

sprinkling of small ponds and meadows add to the area's attractiveness in summer. Snow conditions on the Delta do not appear to be severe for moose, but may be sufficient to discourage use of low shrub types for approximately 90 days each winter. Small patches of dense evergreens or tall willow, scattered among low, forage-producing shrub stands, allow access to shrubs even during heavy snow periods. The most favored wintering areas are a large burn about 30 years old in the region of the McIvor River, and a logged region near Sweetgrass Landing, both of which offer good dispersion of habitat.

USE OF HABITAT

During the summer, 37 percent of 138 moose sightings were in water and 41 percent in meadow associations (Fig. 4). Sightings associated with low willow, tall willow, and conifers decreased in order of decreasing visibility (Fig. 4).

In the fall (September 1 to October 30), 122 moose were sighted, primarily in the tall willow and tall willow-meadow associations which offered browse as food (Fig. 4). During cold weather, shelter and refuge from deep snow became important, and moose moved into heavier forest. Fifty-four percent of 571 observations were of moose in associations including willow, 40 percent in those including deciduous trees, and 37 percent including spruce. Thirty-seven percent of observations were in mixed habitat including more than one major plant form within approximately a 200-yard radius from the moose. In most areas, patches of conifers were nearby, except on the Chipewyan Reserve area where thick, tall willow provided cover.

On all areas of the Delta, even those most heavily used by moose, the impact of browsing is far below the level which could be sustained on the present habitat. Bouckhout (1971) studied the effect of high concentrations of game animals on browse in Elk Island National Park. Total percentage of browsed stems on his plots ranged between 25 percent for cranberry and 76 percent for willow (compare with Table 3). That is, browsing pressure on major shrub species in Elk Island Park, which supports more than eight moose per square mile, is more than three times as heavy

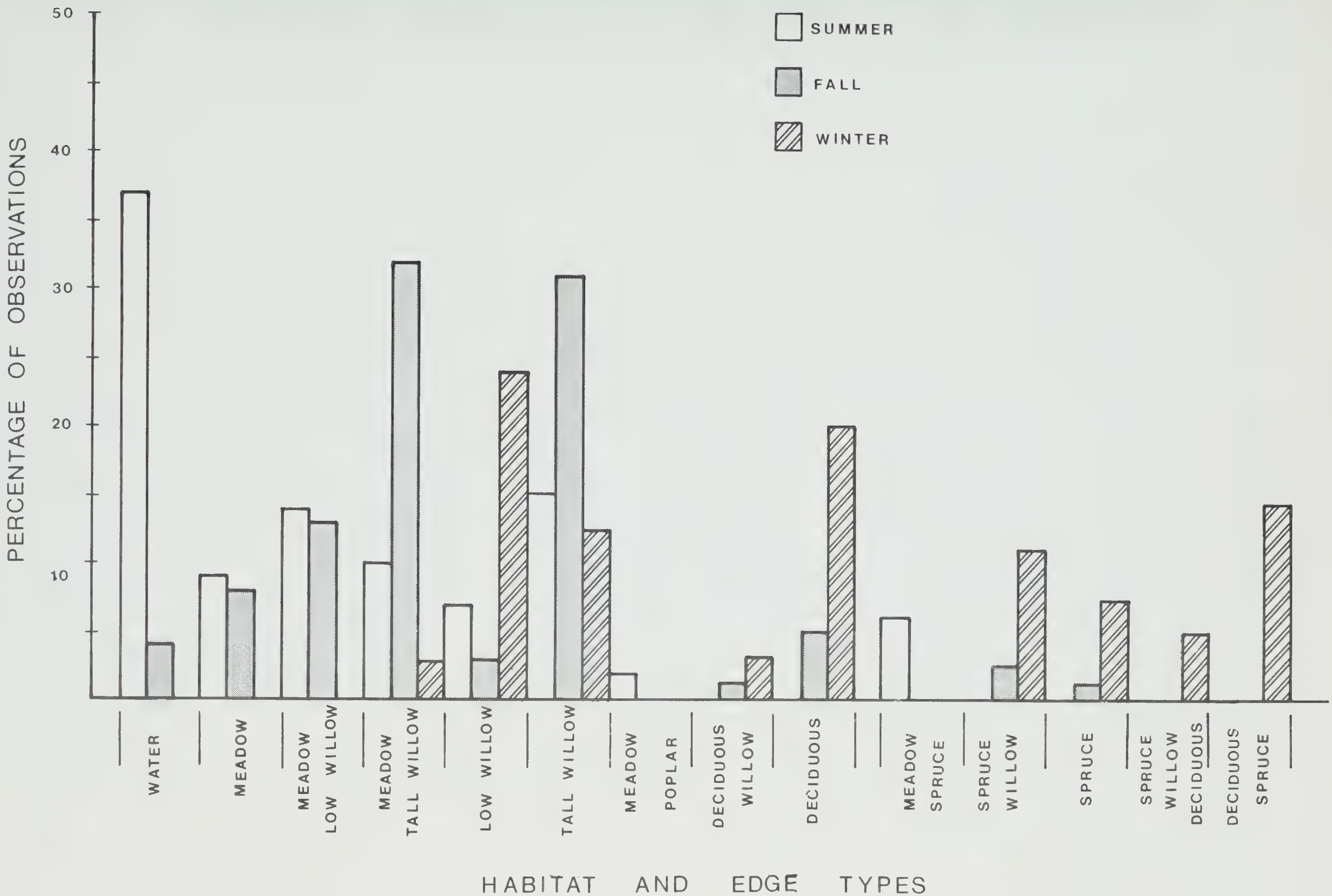

FIG. 4 Moose sightings in different habitat types in summer, fall and winter.

as on the Baril area of the Delta. Bouckhout concluded that the condition of browse in Elk Island Park was somewhat below optimum but not critical. That indicates that browse plants on the Delta are under-used except in a few very small areas (e.g., Steepbank River Flats).

PRESENT CARRYING CAPACITY OF THE DELTA

From the point of view of carrying capacity for moose, the Delta may be divided into four classes, based on subdivisions A to I (Fig. 1), as follows:

Class 1. Subdivisions G, most of H, K, and 1/3 of B (south of Athabasca River to the beginning of the Precambrian Shield), are characterized by a diversity of food-producing shrub types and deciduous and coniferous forest. Based on a subjective comparison with other areas of the Canadian boreal and deciduous-coniferous transition zone familiar to me, I would estimate the optimum density on such range at four animals per square mile (Table 4).

Class 2. Subdivisions C, F, and 1/3 of B (north of the Athabasca River), contain shrub types but little forest. These areas presently carry moose year-round and appear to have a sufficient cover of dense, tall shrubs to provide shelter. I therefore estimate that this land would also support four moose per square mile (Table 4).

Class 3. Subdivisions A, D, F, J, and most of I lack forest stands and have a low percentage of shrub stands. They are composed largely of open water, emergent vegetation and meadow, most of which is of little use to moose. Changing water levels on the Delta will have their greatest effect in lands of this class. After deducting the areas of the large lakes in I and J, I estimate the

Table 4. 1972 carrying capacity for moose on the Peace-Athabasca Delta.

Subdivisions	Approximate Area (less large lakes) (sq. mi.)	Optimum Moose Density (animals/sq. mi.)	Moose Carrying Capacity (no. of animals)
A: Class 3	33	1	33
B: Class 1	60	4	240
Class 2	60	4	240
C: Class 2	33	4	132
D: Class 3	73	1	73
E: Class 3	69	1	69
F: Class 2	134	4	536
G: Class 1	180	4	720
H: Class 1	127	4	508
Class 4	11	8	88
I: Class 3	650	1	650
Class 4	160	8	1280
J: Class 3	166	1	166
K: Class 1	180	4	720
Totals	1936		5455

optimum density of moose in these regions as one per square mile (Table 4).

Class 4. There are two burned or recently logged areas of major importance to moose on the Delta. One is a 25 to 30 year burn covering most of the McIvor River study area (Fig. 1). Much of this burn is regenerating to birch. There are still many openings within the burns producing willows, red osier dogwood, birch, and balsam poplar browse within reach of moose. These openings are heavily utilized. Part of the burn is the Steepbank River flats which, during early winter, supported the highest moose concentrations recorded in this study (Table 1, Fig. 3). At present, this area provides a large browse supply which is heavily used in early winter. At maximum recorded levels of Lake Claire much of this flat would be under water.

Near Sweetgrass Landing is a smaller area where an old burn and recent logging have provided a useful diversity of moose habitat. The highest concentrations of moose recorded in North America have been found in areas burned or logged (Hatter, 1949; Leopold, 1953). I estimate that an optimum moose density for Class 4 would be eight per square mile (Table 4).

EFFECT OF WATER LEVEL CHANGES ON MOOSE POPULATION AND CARRYING CAPACITY

If water levels in the Delta remain at their present (1971) low level or drop even more, the amount of available moose habitat would be expected to rise. This increase would have to await the establishment of stands of tall willow or forest suitable for shelter as well as the invasion of shrub types. Carrying capacity in an area would then rise sharply for several years to four per square mile.

For example, subdivision 1, excluding Lake Claire, contains about 650 square miles. The 19 square miles of forest form the nucleus of the moose range, supported by 68 square miles of tall shrubs. Some of the 206 square miles of low shrubs would be available to moose except during periods of deep snow. Some meadow and emergent stands would be used in summer. Apart from the trees and tall shrubs, about 50 square miles of other vegetation types are presently available to moose. That leaves about 500 square miles of unsuitable habitat which, about 15 years hence, would begin to rise sharply in carrying capacity, with the result in 25 to 30 years of the addition of 400 to 500 square miles of habitat capable of supporting four moose per square mile.

If water levels remain low and stable, succession to a white or black spruce forest will proceed. Interspersion of seral stages will disappear, and homogeneous stands of white spruce will support fewer moose than the earlier mixed stands. At this

point, fire would become important, although even presently either wildfire (unfought) or prescribed burning could greatly increase the capacity of the Delta to support moose. Peterson (1955) states that the most favorable habitat for moose is continual plant succession or regeneration. Moose populations in an area are highest during the early stages of forest succession and decrease as the forest reaches maturity. Mixed rather than pure stands are required for favorable moose habitat.

Further, the encroachment of forest types on the sedge meadows would reduce the available bison range. Fewer bison on the Delta would mean less interaction between moose and bison and might allow increases in moose numbers.

The stabilization of low water levels would also minimize flooding on parts of the Delta, although the Athabasca River would still be subject to occasional floods. This would result in more summer range being available to moose and, again, might allow population increases in some areas.

Conversely, raising water levels on the Delta would have little effect on moose and would not greatly reduce the area of available moose range. Obviously, moose will reach the theoretical carrying capacity of the Delta only with intensive management and severe restriction of hunting. Considering the economic status of Fort Chipewyan and the fact that much of the area is a National Park, this is probably not desirable.

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SECTION O

SIMULATION OF HABITAT SUCCESSION AND WILDLIFE POPULATIONS ON THE PEACE-ATHABASCA DELTA

by

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CANADIAN WILDLIFE SERVICE

Edmonton, Alberta

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ABSTRACT

A computer program was written to accept water levels and water-level fluctuations for Lake Athabasca, and to simulate effects of these on habitat and populations of waterfowl, muskrats, bison, and moose for a number of years into the future. A variety of water-level regimes are tested, including the natural historic regime, the predicted regime with the Bennett Dam in operation and regimes possible under several proposed alternative remedial structures. Under the modified regime that results from full operation of the Bennett Dam, perched basin shoreline important to migratory birds is expected to decrease by approximately 50 percent, waterfowl production will decline an average of 20-25 percent, muskrat populations will decline 40-65 percent, bison habitat is expected to gradually shift to less of meadow and more of shrub type, and moose habitat is expected to increase by approximately 17 percent. Of three fixed-crest water control structures examined for suitability in restoring the natural regime, the rock weir on the Rochers River is the most suitable. Wildlife production could be substantially increased above that possible under the natural regime by compartmenting the Delta and managing water levels to meet specific wildlife requirements.

INTRODUCTION

In the spring of 1971, the Canadian Wildlife Service initiated studies of wildlife populations and their habitat on the Peace-Athabasca Delta under the auspices of the Peace-Athabasca Delta Project. Declining water levels on the Delta since 1968, coincident with the filling of the Williston Reservoir behind the Bennett Dam, prompted the investigation of the effects of a variety of water level regimes on the biota of the Delta. The objectives of the wildlife study were to: (1) ascertain the present populations of major wildlife species following three years of declining water levels; (2) determine from previous inventories the past variation in wildlife populations or harvests as they occurred under historical water level conditions; (3) determine the relationship between wildlife populations and the various water level regimes of Lake Athabasca; (4) determine water level regimes that would be most suitable for maximizing wildlife production; (5) determine the effect on each species of the modified hydrologic regime anticipated under future operation of the Bennett Dam.

Objectives (3), (4) and (5) required a predictive analysis because water levels and wildlife populations change both seasonally and annually. Therefore, simulation on a computer of the ecological system was used to predict population and habitat trends resulting from alternative water regimes.

Because of the immense complexity of the Delta ecosystem, it was necessary to restrict wildlife studies to those species

economically or aesthetically important and those most likely to be influenced by changes in the hydrologic regime. This study therefore concentrated on muskrat, waterfowl, bison and moose as the principal wildlife species or groups.

Initially the plan was to develop a mathematical model using dynamic linear programming that could be of assistance in selecting the most appropriate water management regime for maximum wildlife production. This objective was not realized because the complex habitat relationships made the resulting model too large and too costly to be a useful tool (Anderson, 1971). Instead, a simulation approach was used, whereby a computer program was written to accept a number of topographic, vegetation and wildlife parameters, and a series of water level regimes so that the effect of these water levels on wildlife productivity could be evaluated.

The simulation program first accepts the acreages of each major habitat type, miles of shoreline present, rates of shoreline loss through evaporation, vertical ranges of habitat types, and depths of basins. It then prepares a mathematical contour map of the Delta.

The program then reads the information on 1971 populations (muskrat, moose, bison, and ducks) including numbers of animals in each area of the Delta and/or productivity of these animals, plus, in some cases, information relating to the carrying capacity of the animal species for each habitat type. All of this represents the present condition or status of the

vegetation and animals on the Delta and this completes one major segment of the program.

The second part of the program is the "What happens if ..." section. What happens if the water levels are at one series of levels in 1972, another in 1973, 1974, etc. The program accepts five water levels for every year, one for each of five time periods. For each year, the program updates the plant succession, allows populations to grow according to certain rules, and then takes an inventory at the appropriate time of the items of interest, and stores the results. It then reads another set of water levels and repeats the updating procedure. It will accept up to 98 years of water levels. Finally, when all the years are read, the program prints the answers.

A number of program runs were made, resulting in too large a volume of computer printout to include in this paper. These data are stored on magnetic tape and a copy of the printout including an estimated 1,600 pages is deposited in the Library, Canadian Wildlife Service, Western Region, Edmonton, Canada.

ASSUMPTIONS AND DEFINITIONS USED IN MODEL

SUBDIVISIONS OF THE DELTA

The Delta was divided into ten subdivisions (Figure 1, with subdivisions I and J being grouped into one). The program executes a solution for each subdivision as an entire unit. One subdivision, or any number of them up to ten, can be run. In addition, if A, B and C are all selected, the program stores the results in a total for the Alberta portion and prints this. If E and F are both selected, the program prints the total for the Chipewyan Reserve. If D, G, H, I and J and K are all selected, the program prints the total for the Wood Buffalo National Park. If all ten subdivisions are selected, the program prints the total for the entire Delta.

ECOLOGICAL TIME PERIODS

Fluctuations in water levels affect wildlife populations differently depending upon the seasonal cycle of the animal. Five time intervals were chosen based on ecological significance:

Period 1	May 1 to May 31
Period 2	June 1 to June 30
Period 3	July 1 to August 14
Period 4	August 15 to October 14
Period 5	October 15 to April 30

The major activities of the animals under consideration roughly

coincide with one or more of these seasonal categories and it was important to have a water level input and a measure of water fluctuation for each of these seasons. For example, May 1 - October 14 is approximately the open water period on the Delta, June 1 - August 14 includes the growing season, May 1 - June 30 is approximately the duck nesting season, and October 15 to about April 30 is from freeze-up through the critical over-wintering period for many of the animals.

The effect of a water level during a given time period on a certain animal or habitat type is variable. The program concentrates on the relationship between the water level of the important time period (or periods) and that animal or habitat type.

MATHEMATICAL CONTOUR MAP

Topographic data were required in order to determine how much of the Delta was flooded and to what depth during each of the five time periods under various water levels. As indicated in Appendix I, it was not feasible to survey the entire 1.5 million acre Delta and prepare contour maps of sufficient accuracy to reflect narrow flooding tolerances of the various habitat types. As an alternative, sampling was used to obtain the necessary information on vertical ranges of the habitat zones and the depths of basins. This was combined with the information already obtained from the aerial photographs indicating numbers of acres of each of the major habitat types (Appendix I) and numbers of miles of shoreline within each subdivision of the Delta.

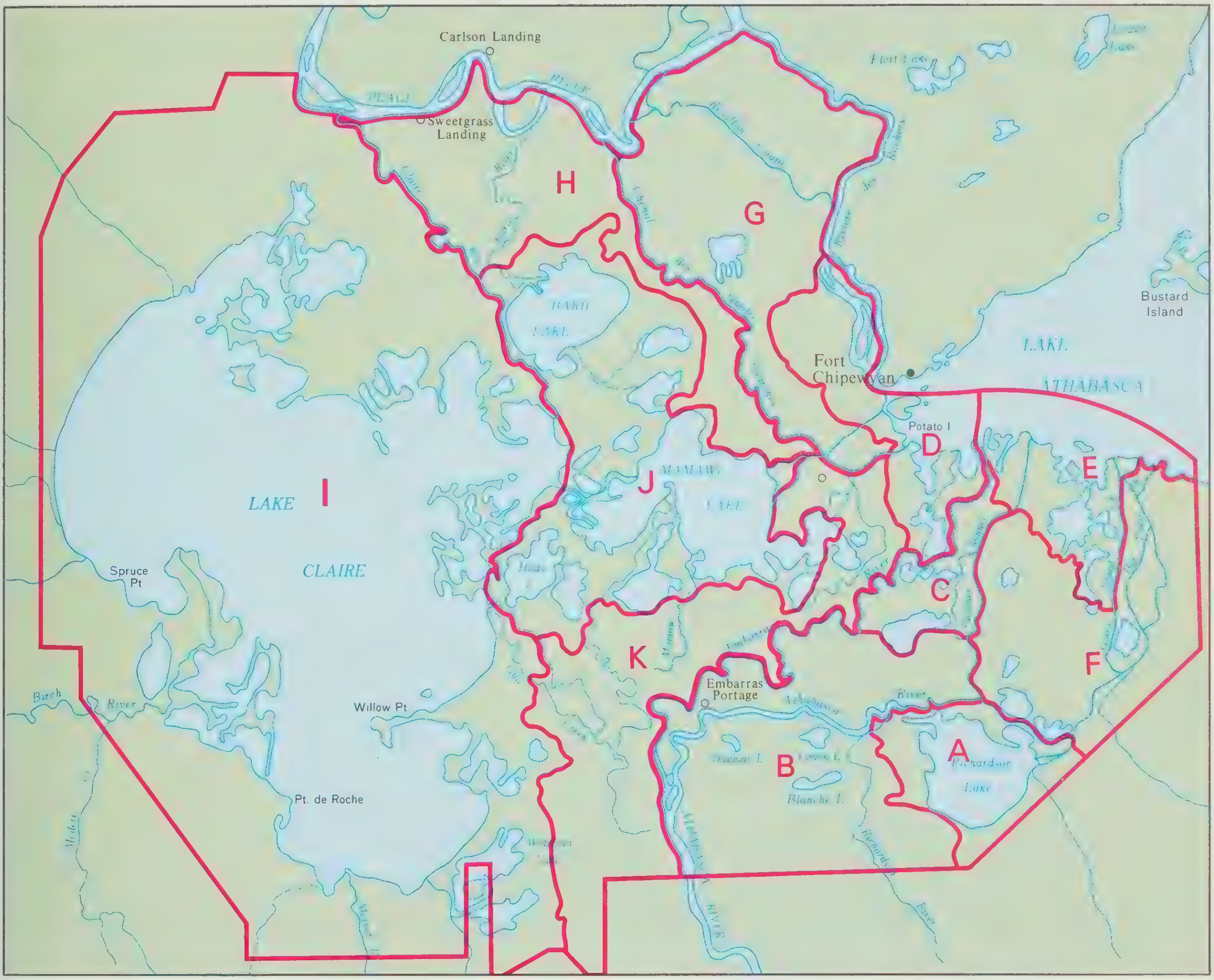

FIG. 1 Subdivisions of the Peace-Athabasca Delta

Each subdivision of the Delta was divided into two sections, the open drainage portion and the perched basin portion. For computation of wildlife population estimates, it was not necessary to have a horizontal spatial presentation of the information but rather only to know numbers of acres falling within each open drainage and closed drainage area. Vertical distribution, however, was important in order to keep track of plant succession, which varied in speed and direction according to depth of water. A major assumption of the model was that, because of high waters prevailing in the early 1960's, this had the effect of vertically ordering habitat types on the landscape (Appendix I). The open drainage basin and the perched basins can be thought of as shallow saucers with a series of contour levels from the bottom to the upper edge of the saucer, each level being represented by a habitat type (Figure 2). The model assumes the following initial vertical positioning of habitat types:

Contour Level 1 - The lowest contour level to which is assigned the open water and emergent vegetation.

Contour Level 2 - Mud flats and immature fen.

Contour Level 3 - Sedge meadows.

Contour Level 4 - Grass meadows.

Contour Level 5 - Low shrub community.

Contour Level 6 - Tall shrub community.

Contour Level 7 - Deciduous forest.

Contour Level 8 - Coniferous forest.

Open Drainage Basins

In general, the basin bottom represents the elevation of the deepest portion of an open drainage lake within the subdivision. For example, in subdivision I-J, the basin bottom would be the elevation of the deepest recorded part of Lake Claire. The boundary between Contour Levels 1 and 2 represents the lake level at the time the 1970 aerial photographs were taken. The boundary between Contour Levels 2 and 3 represents the water level existing during spring 1968 before water levels began to decline. The boundary between Contour Levels 3 and 4 represents the normal full level of perched basins after flood waters have receded.

Because there is no way of determining vertical distribution of emergents from aerial photographs, the model alternates the vertical allocation of water and emergents within Contour Level 1. Within Contour Level 2, the mud flats are allocated to the lower portion and the immature fen is positioned above the mud flats. Table 1 presents the boundary elevations for each of the contour levels and the number of acres lying within each level for the open drainage areas.

Perched Basins

Within each subdivision there is room in the model for eight perched basins, distributed one to each contour level of the open drainage system (Figure 3). The perched basin habitat is initially distributed in the same order of vertical stratification as is the open drainage habitat with the

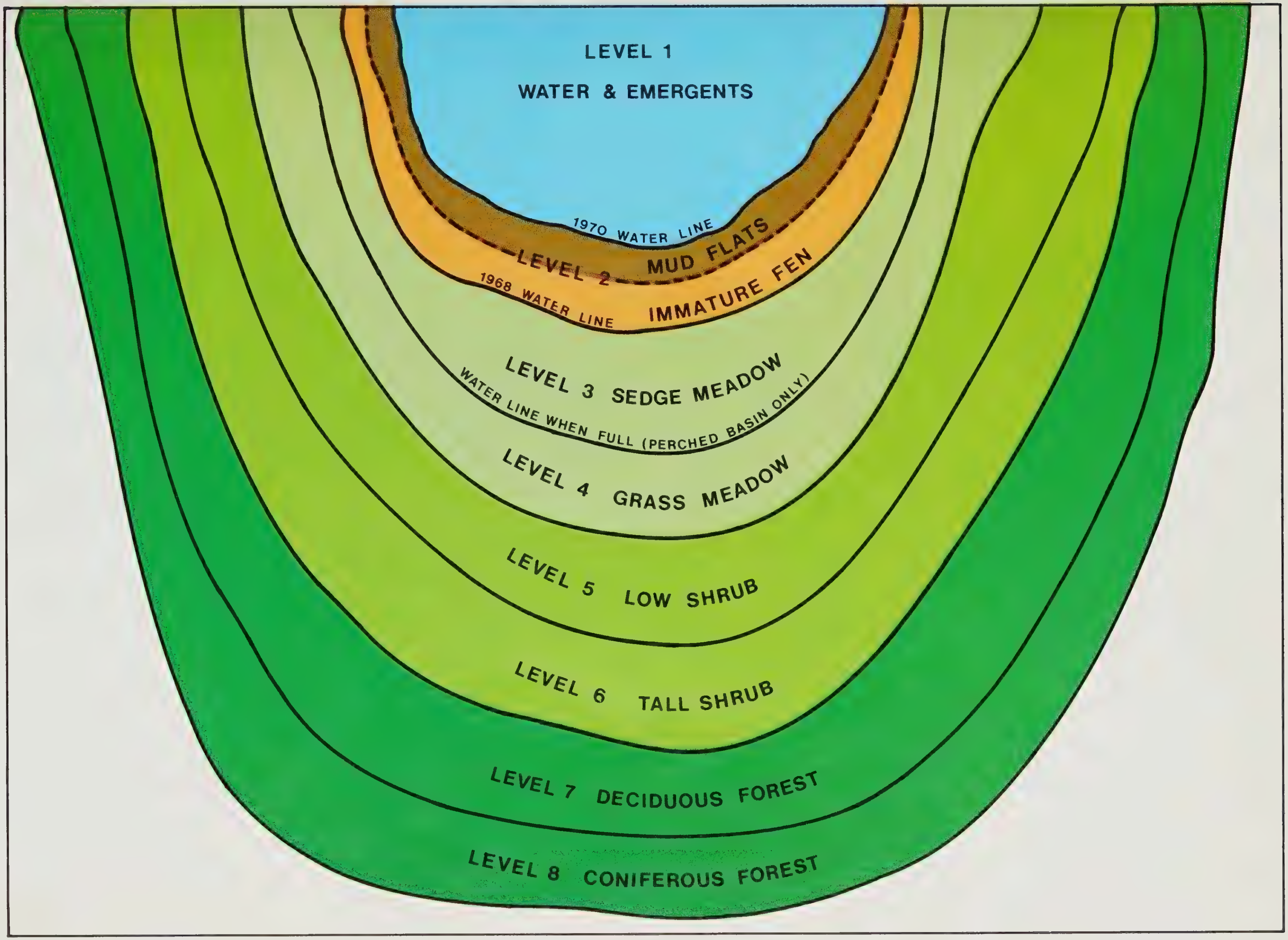

Fig. 2 Diagrammatic representation of initial positioning of habitat types in wildlife model.

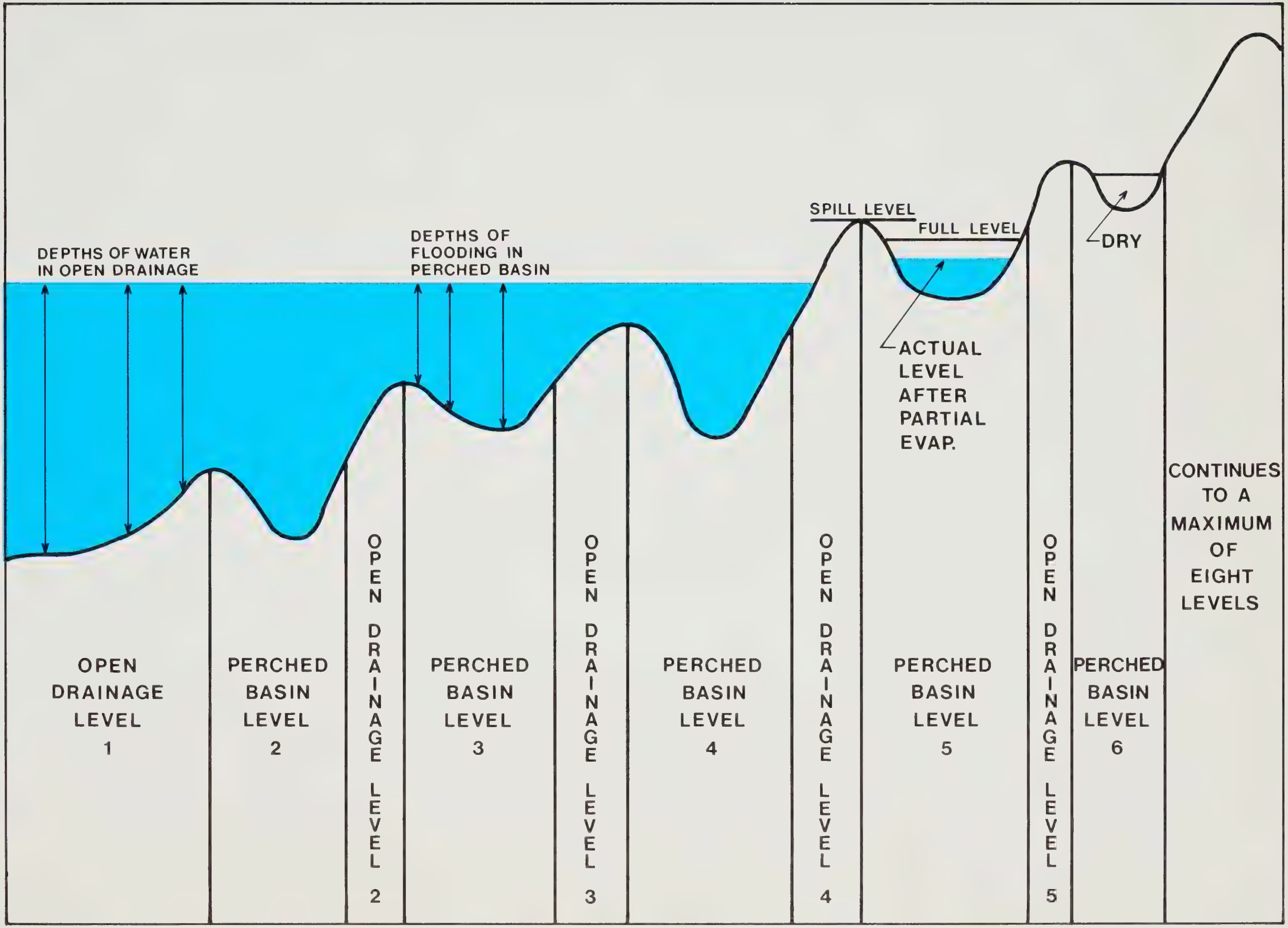

Fig. 3 Cross-section of simulated positioning of perched basins in a subdivision.

Table 1. Assignment of vertical positions of open-drainage basin acres by habitat type.

Contour Level & Habitat	Subdivision A		Subdivision B	
	Elevation	Acres	Elevation	Acres
Basin Bottom	685.4		686.7	
Water		16,206		1,129
Emergents		502		85
Sept. 1970 Water Level	687.8		689.6	
Mud Flats		1,440		430
Imm. Fen		2,560		570
Lower Limit Sedge	689.3		692.0	
Sedge		559		400
Lower Limit Grass	690.6		692.4	
Calamagrostis		186		400
Lower Limit L. Shrub	691.4		692.9	
Low Shrub		3,375		2,750
Lower Limit T. Shrub	693.1		695.2	
Tall Shrub		2,720		2,345
Lower Limit Deciduous	695.2		698.4	
Deciduous		175		1,000
Lower Limit Coniferous	698.6		701.5	
Coniferous		0		775
Upper Limit Coniferous	698.6		704.6	
Total Acres		27,723		9,884

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Table 1. Continued.

Contour Level & Habitat	Subdivision C		Subdivision D	
	Elevation	Acres	Elevation	Acres
Basin Bottom	683.5		680.7	
Water		3,882		3,774
Emergents		378		1,776
Sept. 1970 Water Level	686.5		683.0	
Mud Flats		143		3,420
Imm. Fen		1,357		2,580
Lower Limit Sedge	688.4		684.5	
Sedge		540		16,552
Lower Limit Grass	689.0		686.5	
Calamagrostis		540		5,911
Lower Limit L. Shrub	690.5		687.8	
Low Shrub		5,315		9,475
Lower Limit T. Shrub	692.6		688.5	
Tall Shrub		1,760		1,990
Lower Limit Deciduous	695.0		689.3	
Deciduous		113		0
Lower Limit Coniferous	695.8		690.2	
Coniferous		39		0
Upper Limit Coniferous	696.7		690.2	
Total Acres		13,968		45,478

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Table 1. Continued.

Contour Level & Habitat	Subdivision E		Subdivision F	
	Elevation	Acres	Elevation	Acres
Basin Bottom	680.7		685.2	
Water		3,561		2,145
Emergents		2,277		605
Sept. 1970 Water Level	683.0		686.5	
Mud Flats		9,384		149
Imm. Fen		4,216		996
Lower Limit Sedge	684.5		687.4	
Sedge		10,771		3,120
Lower Limit Grass	686.5		688.3	
Calamagrostis		3,847		780
Lower Limit L. Shrub	687.8		688.6	
Low Shrub		4,835		10,090
Lower Limit T. Shrub	688.5		690.3	
Tall Shrub		2,540		2,609
Lower Limit Deciduous	689.3		693.0	
Deciduous		0		414
Lower Limit Coniferous	690.2		695.5	
Coniferous		0		7
Upper Limit Coniferous	690.2		697.0	
Total Acres		41,431		20,908

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Table 1. Continued.

Contour Level & Habitat	Subdivision G		Subdivision H	
	Elevation	Acres	Elevation	Acres
Basin Bottom	679.0		684.0	
Water		3,980		5,215
Emergents		995		3,625
Sept. 1970 Water Level	682.0		686.0	
Mud Flats		630		268
Imm. Fen		681		1,312
Lower Limit Sedge	685.0		687.5	
Sedge		5,595		3,735
Lower Limit Grass	686.3		688.3	
Calamagrostis		799		2,615
Lower Limit L. Shrub	687.0		689.0	
Low Shrub		10,402		12,070
Lower Limit T. Shrub	687.8		691.5	
Tall Shrub		7,084		13,014
Lower Limit Deciduous	690.0		692.8	
Deciduous		1,794		11,563
Lower Limit Coniferous	691.2		694.7	
Coniferous		4,588		18,714
Upper Limit Coniferous	695.8		696.2	
Total Acres		36,548		72,131

(Continued on next page.)

Table 1. Continued.

Contour Level & Habitat	Subdivision I-J		Subdivision K	
	Elevation	Acres	Elevation	Acres
Basin Bottom	679.5		684.0	
Water		312,172		1,416
Emergents		12,473		354
Sept. 1970 Water Level	684.5		687.5	
Mud Flats		29,130		140
Imm. Fen		40,225		860
Lower Limit Sedge	687.0		689.5	
Sedge		18,890		1,715
Lower Limit Grass	687.7		690.8	
Calamagrostis		19,072		1,715
Lower Limit L. Shrub	689.0		691.5	
Low Shrub		100,728		5,791
Lower Limit T. Shrub	690.0		692.3	
Tall Shrub		37,615		6,542
Lower Limit Deciducus	690.5		693.7	
Deciduous		3,250		1,609
Lower Limit Coniferous	692.5		695.3	
Coniferous		6,222		2,976
Upper Limit Coniferous	695.0		696.0	
Total Acres		576,677		23,118

exception that some of the habitat types may not be present on some of the perched basins. Acreages and shoreline were allocated by habitat type to each contour level according to the percentage of total basins in the subdivision and the distribution of spill levels (Appendix I). Table 2 gives the allocation of perched basin acres and Table 3 presents the allocation of perched shoreline miles. The lower perched basins initially contain water, emergents, mud, immature fen, sedge meadow and perhaps grass meadow. Beginning with Contour Level 5, low shrub is represented. Beginning with Contour Level 6, tall shrub is represented. The perched basin at Level 7 contains deciduous forest and the perched basin at Level 8 contains deciduous forest and coniferous forest if these habitat types are present in the open drainage section.

Additional topographic information was required for the perched basins (Table 4). The highest level of the basin was defined as the spill level and it represents the rim of the perched basin saucer. Flood waters would have to rise to this height in order to fill the basin. A second elevation was required to indicate the level to which water in the perched basin recedes following flooding. This was defined as the full level and is positioned at the initial upper limit of the sedge zone. A third requirement was for information on depth of basin, the vertical distance from basin bottom to basin rim or spill level.

Table 2. Program allocation of perched basin acres among contour levels.

Habitat	Subdivision A -- Contour level								
	1	2	3	4	5	6	7	8	TOTAL
Open Water	0.0	0.0	48.5	72.7	194.0	145.5	24.2	0.0	485.0
Emergents	0.0	0.0	1.5	2.2	6.0	4.5	0.7	0.0	15.0
Mud Flats	0.0	0.0	12.2	18.3	48.8	36.6	6.1	0.0	122.0
Imm. Fen	0.0	0.0	21.7	32.5	86.8	65.1	10.8	0.0	217.0
Carex	0.0	0.0	111.8	167.7	447.2	335.4	55.9	0.0	1,118.0
Calamagrostis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Shrub	0.0	0.0	112.5	168.7	450.0	337.5	56.2	0.0	1,125.0
Tall Shrub	0.0	0.0	0.0	0.0	0.0	777.4	129.6	0.0	907.0
Deciduous	0.0	0.0	0.0	0.0	0.0	0.0	59.0	0.0	59.0
Coniferous	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	0.0	0.0	308.2	462.3	1,232.8	1,702.0	342.7	0.0	4,048.0

Habitat	Subdivision B -- Contour level								
	1	2	3	4	5	6	7	8	TOTAL
Open Water	0.0	1,219.2	711.2	812.8	2,133.6	2,540.0	2,133.6	609.6	10,160.0
Emergents	0.0	91.8	53.5	61.2	160.6	191.2	160.6	45.9	765.0
Mud Flats	0.0	321.2	187.4	214.2	562.2	669.3	562.2	160.6	2,677.0
Imm. Fen	0.0	425.9	248.4	283.9	745.3	887.3	745.3	212.9	3,549.0
Carex	0.0	864.4	504.2	576.2	1,512.6	1,800.7	1,512.6	432.2	7,203.0
Calamagrostis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Shrub	0.0	2,968.8	1,731.8	1,979.2	5,195.4	6,185.0	5,195.4	1,484.4	24,740.0
Tall Shrub	0.0	0.0	0.0	0.0	0.0	10,146.6	8,523.2	2,435.2	21,105.0
Deciduous	0.0	0.0	0.0	0.0	0.0	0.0	6,962.7	1,989.3	8,952.0
Coniferous	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6,941.0	6,941.0
Total	0.0	5,891.3	3,436.6	3,927.5	10,309.7	22,420.1	25,795.6	14,311.2	86,091.9

(Continued on next page.)

Table 2. Continued.

Habitat	Subdivision C -- Contour level								
	1	2	3	4	5	6	7	8	TOTAL
Open Water	0.0	93.6	280.8	187.2	561.6	374.4	374.4	0.0	1,872.0
Emergents	0.0	9.3	27.9	18.6	55.8	37.2	37.2	0.0	186.0
Mud Flats	0.0	3.4	10.3	6.9	20.7	13.8	13.8	0.0	69.0
Imm. Fen	0.0	32.9	98.8	65.9	197.7	131.8	131.8	0.0	659.0
Carex	0.0	26.9	80.8	53.9	161.7	107.8	107.8	0.0	539.0
Calamagrostis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Shrub	0.0	130.7	392.2	261.5	784.5	523.0	523.0	0.0	2,615.0
Tall Shrub	0.0	0.0	0.0	0.0	0.0	434.5	434.5	0.0	869.0
Deciduous	0.0	0.0	0.0	0.0	0.0	0.0	56.0	0.0	56.0
Coniferous	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	0.0	297.0	891.0	594.0	1,782.0	1,622.5	1,678.5	0.0	6,865.0

Habitat	Subdivision D -- Contour level								
	1	2	3	4	5	6	7	8	TOTAL
Open Water	0.0	0.0	40.4	50.5	40.4	70.7	0.0	0.0	202.0
Emergents	0.0	0.0	19.0	23.8	19.0	33.2	0.0	0.0	95.0
Mud Flats	0.0	0.0	24.6	30.7	24.6	43.0	0.0	0.0	123.0
Imm. Fen	0.0	0.0	18.4	23.0	18.4	32.2	0.0	0.0	92.0
Carex	0.0	0.0	236.4	295.5	236.4	413.7	0.0	0.0	1,182.0
Calamagrostis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Shrub	0.0	0.0	98.0	122.5	98.0	171.5	0.0	0.0	490.0
Tall Shrub	0.0	0.0	0.0	0.0	0.0	103.0	0.0	0.0	103.0
Deciduous	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coniferous	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	0.0	0.0	436.8	546.0	436.8	867.4	0.0	0.0	2,287.0

(Continued on next page.)

Table 2. Continued.

Habitat	Subdivision E -- Contour level								
	1	2	3	4	5	6	7	8	TOTAL
Open Water	0.0	0.0	37.4	46.7	37.4	65.4	0.0	0.0	187.0
Emergents	0.0	0.0	24.0	30.0	24.0	42.0	0.0	0.0	120.0
Mud Flats	0.0	0.0	99.0	123.7	99.0	173.2	0.0	0.0	495.0
Imm. Fen	0.0	0.0	44.4	55.5	44.4	77.7	0.0	0.0	222.0
Carex	0.0	0.0	153.8	192.2	153.8	269.1	0.0	0.0	769.0
Calamagrostis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Shrub	0.0	0.0	51.0	63.8	51.0	89.2	0.0	0.0	255.0
Tall Shrub	0.0	0.0	0.0	0.0	0.0	133.0	0.0	0.0	133.0
Deciduous	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	0.0	0.0	409.6	512.0	409.6	849.8	0.0	0.0	2,181.0

Habitat	Subdivision F -- Contour level								
	1	2	3	4	5	6	7	8	TOTAL
Open Water	0.0	128.7	836.7	257.4	2,574.4	1,995.2	643.6	0.0	6,436.0
Emergents	0.0	36.3	236.1	72.6	726.4	563.0	181.6	0.0	1,816.0
Mud Flats	0.0	8.7	56.5	17.4	174.0	134.8	43.5	0.0	435.0
Imm. Fen	0.0	58.2	378.3	116.4	1,164.0	902.1	291.0	0.0	2,910.0
Carex	0.0	234.0	1,521.3	468.1	4,680.8	3,627.6	1,170.2	0.0	11,702.0
Calamagrostis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Shrub	0.0	605.4	3,935.1	1,210.8	12,108.0	9,383.7	3,027.0	0.0	30,270.0
Tall Shrub	0.0	0.0	0.0	0.0	0.0	5,917.2	1,908.8	0.0	7,826.0
Deciduous	0.0	0.0	0.0	0.0	0.0	0.0	1,240.0	0.0	1,240.0
Coniferous	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	0.0	1,071.4	6,964.0	2,142.8	21,427.6	22,523.6	8,505.7	0.0	62,635.0

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Table 2. Continued.

Habitat	Subdivision G -- Contour level								
	1	2	3	4	5	6	7	8	TOTAL
Open Water	0.0	0.0	298.5	298.5	1,194.0	1,194.0	1,791.0	1,194.0	5,970.0
Emergents	0.0	0.0	74.5	74.5	298.0	298.0	447.0	298.0	1,490.0
Mud Flats	0.0	0.0	23.7	23.7	95.0	95.0	142.5	95.0	475.0
Imm. Fen	0.0	0.0	25.7	25.7	103.0	103.0	154.5	103.0	515.0
Carex	0.0	0.0	479.5	479.5	1,918.0	1,918.0	2,877.0	1,918.0	9,590.0
Calamagrostis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Shrub	0.0	0.0	780.1	780.1	3,120.6	3,120.6	4.680.9	3,120.6	15,603.0
Tall Shrub	0.0	0.0	0.0	0.0	0.0	3,036.0	4,554.0	3,036.0	10,626.0
Deciduous	0.0	0.0	0.0	0.0	0.0	0.0	1,614.0	1,076.0	2,690.0
Coniferous	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6,882.0	6,882.0
Total	0.0	0.0	1,682.1	1,682.1	6,728.6	9,764.6	16,260.9	17,722.6	53,841.0

Habitat	Subdivision H -- Contour level								
	1	2	3	4	5	6	7	8	TOTAL
Open Water	0.0	0.0	46.0	184.0	230.0	276.0	138.0	46.0	920.0
Emergents	0.0	0.0	32.0	128.0	160.0	192.0	96.0	32.0	640.0
Mud Flats	0.0	0.0	2.4	9.6	12.0	14.4	7.2	2.4	48.0
Imm. Fen	0.0	0.0	11.6	46.6	58.3	69.9	34.9	11.6	233.0
Carex	0.0	0.0	56.0	224.0	280.0	336.0	168.0	56.0	1,120.0
Calamagrostis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Shrub	0.0	0.0	106.5	426.0	532.5	639.0	319.5	106.5	2,130.0
Tall Shrub	0.0	0.0	0.0	0.0	0.0	1,800.0	900.0	300.0	3,000.0
Deciduous	0.0	0.0	0.0	0.0	0.0	0.0	1,530.0	510.0	2,040.0
Coniferous	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3,302.0	3,302.0
Total	0.0	0.0	254.5	1,018.2	1,272.7	3,327.3	3,193.6	4,366.5	13,433.0

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Table 2. Continued.

Habitat	Subdivision I-J -- Contour level 1	2	3	4	5	6	7	8	TOTAL
Open Water	0.0	1,232.4	5,853.9	9,551.1	9,243.0	2,156.7	2,772.9	0.0	30,810.0
Emergents	0.0	800.0	3,800.0	6,200.0	6,000.0	1,400.0	1,800.0	0.0	20,000.0
Mud Flats	0.0	164.1	779.4	1,271.6	1,230.6	287.1	369.2	0.0	4,102.0
Imm. Fen	0.0	250.7	1,190.0	1,943.1	1,880.4	438.8	564.1	0.0	6,268.0
Carex	0.0	3,800.0	18,050.0	29,450.0	28,500.0	6,650.0	8,550.0	0.0	94,999.8
Calamagrostis	0.0	2,274.0	10,801.3	17,623.2	17,054.7	3,979.4	5,116.4	0.0	56,849.0
Low Shrub	0.0	0.0	0.0	0.0	32,608.7	7,608.7	9,782.6	0.0	50,000.0
Tall Shrub	0.0	0.0	0.0	0.0	0.0	7,437.5	9,562.5	0.0	17,000.0
Deciduous	0.0	0.0	0.0	0.0	0.0	0.0	3,280.0	0.0	3,280.0
Coniferous	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	0.0	8,521.2	40,475.5	66,038.9	96,517.3	29,958.2	41,797.7	0.0	283,308.7

Habitat	Subdivision K -- Contour level 1	2	3	4	5	6	7	8	TOTAL
Open Water	0.0	1,132.6	566.3	283.1	849.4	1,132.6	1,132.6	566.3	5,663.0
Emergents	0.0	283.2	141.6	70.8	212.4	283.2	283.2	141.6	1,416.0
Mud Flats	0.0	18.2	9.1	4.5	13.6	18.2	18.2	9.1	91.0
Imm. Fen	0.0	111.4	55.7	27.8	83.5	111.4	111.4	55.7	557.0
Carex	0.0	2,744.6	1,372.3	686.1	2,058.4	2,744.6	2,744.6	1,372.3	13,723.0
Calamagrostis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Shrub	0.0	4,626.0	2,313.0	1,156.5	3,469.5	4,626.0	4,626.0	2,313.0	23,130.0
Tall Shrub	0.0	0.0	0.0	0.0	0.0	10,468.0	10,468.0	5,234.0	26,170.0
Deciduous	0.0	0.0	0.0	0.0	0.0	0.0	4,290.0	2,145.0	6,435.0
Coniferous	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11,890.0	11,890.0
Total	0.0	8,916.0	4,458.0	2,229.0	6,687.0	19,384.0	23,674.0	23,727.0	89,074.9

Table 3. Program allocation of perched basin shoreline (miles) among contour levels.

Habitat	Subdivision A -- Contour level								
	1	2	3	4	5	6	7	8	TOTAL
Mud Flats	0.0	0.0	2.1	3.2	8.4	6.3	1.1	0.0	21.1
Imm. Fen	0.0	0.0	2.2	3.3	8.9	6.7	1.1	0.0	22.3
Meadow	0.0	0.0	1.2	1.8	4.9	3.7	0.6	0.0	12.3
Low Shrub	0.0	0.0	1.1	1.7	4.5	3.4	0.6	0.0	11.2
Tall Shrub	0.0	0.0	0.0	0.0	0.0	7.5	1.3	0.0	8.8
Deciduous	0.0	0.0	0.0	0.0	0.0	0.0	3.4	0.0	3.4
Coniferous	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rock	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1
Total	0.0	0.0	6.7	10.0	26.8	27.6	8.0	0.1	79.2

Habitat	Subdivision B -- Contour level								
	1	2	3	4	5	6	7	8	TOTAL
Mud Flats	0.0	10.3	6.0	6.9	18.1	21.5	18.1	5.2	86.2
Imm. Fen	0.0	33.6	19.6	22.4	58.9	70.1	58.9	16.8	280.4
Meadow	0.0	20.9	12.2	13.9	36.6	43.5	36.6	10.4	174.1
Low Shrub	0.0	29.5	17.2	19.6	51.6	61.4	51.6	14.7	245.5
Tall Shrub	0.0	0.0	0.0	0.0	0.0	111.8	93.9	26.8	232.5
Deciduous	0.0	0.0	0.0	0.0	0.0	0.0	73.5	21.0	94.5
Coniferous	0.0	0.0	0.0	0.0	0.0	0.0	0.0	72.7	72.7
Rock	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	1.7
Total	0.0	94.3	55.0	62.9	165.1	308.3	332.5	169.4	1,187.6

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Table 3. Continued.

Habitat	Subdivision C -- Contour level								
	1	2	3	4	5	6	7	8	TOTAL
Mud Flats	0.0	0.1	0.2	0.1	0.4	0.3	0.3	0.0	1.3
Imm. Fen	0.0	1.0	3.0	2.0	6.0	4.0	4.0	0.0	20.0
Meadow	0.0	0.2	0.5	0.4	1.1	0.7	0.7	0.0	3.6
Low Shrub	0.0	0.9	2.7	1.8	5.5	3.7	3.7	0.0	18.3
Tall Shrub	0.0	0.0	0.0	0.0	0.0	3.6	3.6	0.0	7.3
Deciduous	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.2
Coniferous	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rock	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	0.0	2.2	6.5	4.3	13.0	12.3	12.5	0.0	50.7

Habitat	Subdivision D -- Contour level								
	1	2	3	4	5	6	7	8	TOTAL
Mud Flats	0.0	0.0	0.8	1.0	0.8	1.5	0.0	0.0	4.2
Imm. Fen	0.0	0.0	3.2	4.0	3.2	5.6	0.0	0.0	15.9
Meadow	0.0	0.0	7.2	8.9	7.2	12.5	0.0	0.0	35.8
Low Shrub	0.0	0.0	10.2	12.7	10.2	17.8	0.0	0.0	50.8
Tall Shrub	0.0	0.0	0.0	0.0	0.0	11.9	0.0	0.0	11.9
Deciduous	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coniferous	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pock	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5
Total	0.0	0.0	21.3	26.7	21.3	49.2	0.0	0.5	119.1

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Table 3. Continued.

Habitat	Subdivision E -- Contour level								
	1	2	3	4	5	6	7	8	TOTAL
Mud Flats	0.0	0.0	5.6	7.0	5.6	9.8	0.0	0.0	28.0
Imm. Fen	0.0	0.0	3.1	3.9	3.1	5.5	0.0	0.0	15.6
Meadow	0.0	0.0	4.6	5.8	4.6	8.1	0.0	0.0	23.1
Low Shrub	0.0	0.0	3.2	4.0	3.2	5.6	0.0	0.0	16.0
Tall Shrub	0.0	0.0	0.0	0.0	0.0	1.7	0.0	0.0	1.7
Deciduous	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coniferous	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rock	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	0.0	0.0	16.5	20.7	16.5	30.6	0.0	0.0	84.4

Habitat	Subdivision F -- Contour level								
	1	2	3	4	5	6	7	8	TOTAL
Mud Flats	0.0	0.3	1.8	0.6	5.6	4.3	1.4	0.0	13.9
Imm. Fen	0.0	3.0	19.3	5.9	59.3	46.0	14.8	0.0	148.3
Meadow	0.0	3.8	24.5	7.5	75.5	58.5	18.9	0.0	188.7
Low Shrub	0.0	5.6	36.6	11.3	112.6	87.3	28.2	0.0	281.6
Tall Shrub	0.0	0.0	0.0	0.0	0.0	44.8	14.5	0.0	59.3
Deciduous	0.0	0.0	0.0	0.0	0.0	0.0	47.3	0.0	47.3
Coniferous	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rock	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	0.0	12.6	82.2	25.3	253.0	240.9	125.0	0.0	739.1

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Table 3. Continued.

Habitat	Subdivision G -- Contour level								
	1	2	3	4	5	6	7	8	TOTAL
Mud Flats	0.0	0.0	1.6	1.6	6.3	6.3	9.4	6.3	31.3
Imm. Fen	0.0	0.0	0.6	0.6	2.5	2.5	3.7	2.5	12.3
Meadow	0.0	0.0	16.8	16.8	67.4	67.4	101.1	67.4	337.0
Low Shrub	0.0	0.0	13.5	13.5	54.0	54.0	81.0	54.0	270.0
Tall Shrub	0.0	0.0	0.0	0.0	0.0	38.3	57.5	38.3	134.2
Deciduous	0.0	0.0	0.0	0.0	0.0	0.0	22.3	14.8	37.1
Coniferous	0.0	0.0	0.0	0.0	0.0	0.0	0.0	76.6	76.6
Rock	0.0	0.0	0.0	0.0	0.0	0.0	0.0	114.3	114.3
Total	0.0	0.0	32.5	32.5	130.1	168.5	275.0	374.2	1,012.8

Habitat	Subdivision H -- Contour level								
	1	2	3	4	5	6	7	8	TOTAL
Mud Flats	0.0	0.0	0.6	2.4	3.0	3.7	1.8	0.6	12.2
Imm. Fen	0.0	0.0	1.4	5.6	7.0	8.4	4.2	1.4	27.9
Meadow	0.0	0.0	6.3	25.2	31.5	37.8	18.9	6.3	125.9
Low Shrub	0.0	0.0	6.8	27.2	34.0	40.8	20.4	6.8	136.0
Tall Shrub	0.0	0.0	0.0	0.0	0.0	75.1	37.6	12.5	125.2
Deciduous	0.0	0.0	0.0	0.0	0.0	0.0	42.0	14.0	56.0
Coniferous	0.0	0.0	0.0	0.0	0.0	0.0	0.0	117.2	117.2
Rock	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.2	4.2
Total	0.0	0.0	15.1	60.4	75.5	165.7	124.9	163.0	604.6

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Table 3. Continued.

Habitat	Subdivision I-J -- Contour level								
	1	2	3	4	5	6	7	8	TOTAL
Mud Flats	0.0	21.4	101.6	165.7	160.4	37.4	48.1	0.0	534.6
Imm. Fen	0.0	30.6	145.6	237.5	229.8	53.6	68.9	0.0	766.1
Meadow	0.0	60.6	287.7	469.5	454.3	106.0	136.3	0.0	1,514.4
Low Shrub	0.0	30.6	145.5	237.5	229.8	53.6	68.9	0.0	766.0
Tall Shrub	0.0	0.0	0.0	0.0	0.0	117.6	151.2	0.0	268.8
Deciduous	0.0	0.0	0.0	0.0	0.0	0.0	25.0	0.0	25.0
Coniferous	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rock	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.1	3.1
Total	0.0	143.2	680.4	1,110.1	1,074.3	368.3	498.5	3.1	3,878.0

Habitat	Subdivision K -- Contour level								
	1	2	3	4	5	6	7	8	TOTAL
Mud Flats	0.0	0.8	0.4	0.2	0.6	0.8	0.8	0.4	4.0
Imm. Fen	0.0	8.0	4.0	2.0	6.0	8.0	8.0	4.0	40.0
Meadow	0.0	28.8	14.4	7.2	21.6	28.8	28.8	14.4	144.2
Low Shrub	0.0	38.5	19.2	9.6	28.9	38.5	38.5	19.2	192.5
Tall Shrub	0.0	0.0	0.0	0.0	0.0	99.2	99.2	49.6	247.9
Deciduous	0.0	0.0	0.0	0.0	0.0	0.0	46.5	23.2	69.7
Coniferous	0.0	0.0	0.0	0.0	0.0	0.0	0.0	78.3	78.3
Rock	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.9	7.9
Total	0.0	76.1	38.1	19.0	57.1	175.3	221.8	197.1	784.5

Table 4. Topographic characteristics assigned to perched basins in model, based on topographic surveys cited in Appendix I.

Contour Level	Subdivision A			Subdivision B		
	Upper Edge (Spill Level)	Full Elevation	Depth (Feet)	Upper Edge (Spill Level)	Full Elevation	Depth (Feet)
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	691.7	690.8	2.6
3	690.1	689.1	3.0	692.3	691.0	3.4
4	690.8	689.9	4.5	692.7	691.9	4.5
5	692.2	690.4	4.8	694.7	692.6	5.4
6	694.3	692.6	6.7	697.0	693.8	6.7
7	697.6	693.8	6.9	700.6	696.4	8.8
8	0.0	0.0	0.0	703.2	698.8	5.0

Contour Level	Subdivision C			Subdivision D		
	Upper Edge (Spill Level)	Full Elevation	Depth (Feet)	Upper Edge (Spill Level)	Full Elevation	Depth (Feet)
1	0.0	0.0	0.0	0.0	0.0	0.0
2	687.8	687.0	2.8	0.0	0.0	0.0
3	688.8	688.2	2.8	685.6	685.0	2.3
4	690.3	689.0	3.5	687.5	687.0	2.6
5	692.4	690.5	4.1	688.4	687.8	2.2
6	694.5	692.0	4.1	689.0	688.2	2.5
7	695.4	693.2	4.1	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0

Contour Level	Subdivision E			Subdivision F		
	Upper Edge (Spill Level)	Full Elevation	Depth (Feet)	Upper Edge (Spill Level)	Full Elevation	Depth (Feet)
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	686.9	686.1	3.2
3	686.0	685.8	0.7	688.0	687.3	3.5
4	687.4	687.0	1.4	688.4	687.9	3.7
5	688.3	687.8	1.9	689.8	687.3	4.5
6	688.9	687.9	2.7	691.6	688.5	5.4
7	0.0	0.0	0.0	694.4	692.2	5.5
8	0.0	0.0	0.0	0.0	0.0	0.0

(Continued on next page.)

Table 4. Continued.

Contour Level	Subdivision G Upper Edge (Spill Level)	Subdivision G Full Elevation	Subdivision G Depth (Feet)	Subdivision H Upper Edge (Spill Level)	Subdivision H Full Elevation	Subdivision H Depth (Feet)
1	0.0	0.0	0.0	0.0		
		0.0				0.0
2	0.0	0.0	0.0	0.0	0.0	0.0
3	686.3	685.0	4.5	687.9	687.0	3.0
4	686.8	685.8	5.0	688.7	687.6	4.4
5	687.6	686.9	7.5	689.8	688.1	5.0
6	689.5	687.7	6.8	692.4	690.3	5.2
7	691.2	688.0	9.0	694.1	692.4	5.7
8	693.4	690.2	9.8	695.7	693.6	6.3

Contour Level	Subdivision I-J Upper Edge (Spill Level)	Subdivision I-J Full Elevation	Subdivision I-J Depth (Feet)	Subdivision K Upper Edge (Spill Level)	Subdivision K Full Elevation	Subdivision K Depth (Feet)
1	0.0	0.0	0.0	0.0	0.0	0.0
2	686.3	686.1	0.7	688.8	688.4	2.4
3	687.2	686.8	1.4	690.4	689.9	3.6
4	688.2	687.5	2.2	691.2	690.8	4.2
5	689.4	688.2	3.8	692.0	689.4	5.0
6	691.8	688.3	5.6	693.4	689.9	6.6
7	692.0	688.5	6.7	694.7	690.1	9.5
8	0.0	0.0	0.0	695.8	693.0	9.6

SIMULATING HYDROLOGIC PROCESSES

The program initially establishes water levels for each of the subdivisions in the open drainage portion and on all of the perched basins. Water levels for fall 1970 are defined as occurring at the boundary between Contour Level 1 and Contour Level 2, i.e., the lower limit of the mud flats zone.

Following this, the program accepts five water levels each year representing levels of Lake Athabasca occurring within each of the five ecological time periods. For each subdivision, the program adjusts the Lake Athabasca levels to compensate for the slope of the Delta in relation to rivers flowing into Lake Athabasca and the lake itself. Constants used in adjusting open-drainage water levels in each subdivision are as follows:

Subdivision	Constant Added to Lake Athabasca Water Level
A	+3.2
B	+4.6
C	+1.7
D	0.0
E	0.0
F	+1.9
G	0.0
H	0.0
I-J	0.0
K	+3.2

Fluctuations in water levels within a time period can be

critical to wildlife productivity. In nature, these fluctuations are caused by wind setup or seiches and by increased or decreased flows into and out of Lake Athabasca. The program accepts a maximum level and a minimum level for each of the five time periods of the ecological year. The maximum level is defined as that level which is exceeded ten percent of the time in the time period. The minimum level is defined as the level which is exceeded 90 percent of the time within the time period. Table 5 presents the values used in the various computer runs for water fluctuation within each time period.

Water level changes occurring in each of the perched basins are more complicated. These basins are flooded or filled depending upon the elevation of the open-drainage water level. Perched basin levels are adjusted during each of the five time periods as required. If the open-drainage water level exceeds the spill level of the basin, the perched basin is flooded during that time period to the water level of the open drainage basin. Following the flooded condition, if the open-drainage water level recedes to below the perched basin spill level, the perched basin water level recedes to the defined full level. The full level, as previously mentioned, is the level of the upper edge of the sedge meadow in 1970.

Each year, if the perched basins are not flooded, water levels decrease by an amount which results in a constant decrease in acres flooded and a constant reduction in shoreline length as follows:

Table 5. Water level departures from average, occurring during each ecological time period on open drainage basins.

Time Period	Upward Departure--Exceeded only 10% of the Time				
	Natural Regime	Modified Regime	Slave Constriction	Rochers Constriction	Rochers Weir
May 1-May 31	0.8'	0.6'	0.7'	0.6'	0.6'
June 1-June 30	1.3'	0.3'	0.4'	0.3'	0.3'
July 1-August 14	0.6'	0.4'	0.4'	0.3'	0.3'
August 15-October 14	1.3'	0.3'	0.9'	0.6'	0.6'
October 15-April 30	1.6'	0.8'	0.9'	1.2'	1.1'

Time Period	Downward Depature--Exceeded only 10% of the Time				
	Natural Regime	Modified Regime	Slave Constriction	Rochers Constriction	Rochers Weir
May 1-May 31	0.8'	0.6'	0.6'	0.6'	0.6'
June 1-June 30	1.1'	0.3'	0.3'	0.3'	0.3'
July 1-August 14	0.5'	0.3'	0.4'	0.3'	0.2'
August 15-October 14	1.0'	0.2'	0.8'	0.5'	0.5'
October 15-April 30	1.6'	0.8'	0.9'	1.1'	1.1'

Subdivision	Annual Percentage Evaporation Loss
A	8
B	7
C	12
D	12
E	12
F	10
G	7
H	7
I-J	12
K	7

Shoreline length for a full perched basin was determined by the following relationship:

$$\text{Full Length} = \frac{100 \text{ ('1970 Length')}}{[\ 100 - 3 \text{ (Percentage Evap. Loss)}\ ]}$$

The constant '3' was used because three summers had passed without refilling the perched basins, and hence the 1970 shore length had been reduced from the full level by three times the average annual evaporation loss.

Given no filling for a number of years, the basin continues to lose water annually (occurring on May 1) at the same rate until it is defined as being dry. When that occurs, the shoreline miles equals zero and the area above water equals the total acreage of the perched basin. Water in a perched basin does not recede below the defined full level if the basin was flooded

during either time period 4 or 5 of the previous year. There are assumed to be no maximum and minimum fluctuations on the perched basins unless the basin is flooded because fluctuations on small perched basins are negligible for ecological purposes.

SIMULATING PLANT SUCCESSION

Following the allocation of the initial habitat types to the various contour levels, the program updates the habitat on each of the contours of each open drainage and perched basin portion of the subdivision. Plant succession advances, is retarded, or remains the same depending upon the depth or absence of water on each contour level during the growing season (time periods 2 and 3). The general sequence of succession for habitat above water is shown in Figure 4. The programming of succession involved assigning each contour acreage an identification number coded as an individual habitat type (Table 6). The model begins with the year 1970 with the water areas identified as 101, emergents as 102, and mud as 104. Immature fen begins as 106, the second year of growth, since this community has been in existence for two years. For the pre-1968 communities Carex begins as 152, Calamagrostis as 159, low shrub as 169, tall shrub as 117, deciduous as 142 and coniferous as 143.

Each year that the plant community is not flooded during the growing season (time period 2 or 3), the habitat advances one number until it reaches the end of the chain (Table 6). Thus, water 101 advances to mud 104 to immature fen 105 and proceeds serially through 140 as long as the ground is not flooded. Sedge

Table 6. Coding used in plant succession portion of computer model for succession above water.

Succession on recently exposed areas	Succession on Pre-1968 Established Communities
101 - Water	151 - Carex 1
102 - Emergents	152 - Carex 2
103 - Mud-water fluctuating	153 - Carex 3
	154 - Carex 4
104 - Mud	155 - Carex 5
105 - Immature fen 1	156 - Carex 6
106 - Immature fen 2	157 - Carex 7
107 - Carex 1	158 Calamagrostis 1
108 - Carex 2	159 Calamagrostis 2
109 - Calamagrostis 1	160 - Calamagrostis 3
110 - Calamagrostis 2	161 - Calamagrostis 4
111 - Low Shrub 1	162 - Calamagrostis 5
112 - Low Shrub 2	163 - Calamagrostis 6
113 - Low Shrub 3	164 - Calamagrostis 7
114 - Low Shrub 4	165 - Calamagrostis 8
115 - Low Shrub 5	166 - Calamagrostis 9
116 - Tall Shrub 1	167 - Calamagrostis 10
117 - Tall Shrub 2	168 - Low Shrub 1
118 - Tall Shrub 3	169 - Low Shrub 2
119 - Tall Shrub 4	170 - Low Shrub 3
120 - Tall Shrub 5	171 - Low Shrub 4
121 - Tall Shrub 6	172 - Low Shrub 5
122 - Tall Shrub 7	173 - Low Shrub 6
123 - Tall Shrub 8	174 - Low Shrub 7
124 - Tall Shrub 9	175 - Low Shrub 8
125 - Tall Shrub 10	176 - Low Shrub 9
126 - Tall Shrub 11	177 - Low Shrub 10
127 - Tall Shrub 12	transfer to 116 for
128 - Tall Shrub 13	Tall shrub 1 and
129 - Tall Shrub 14	continue.
130 - Tall Shrub 15	
131 - Tall Shrub 16	
132 - Tall Shrub 17	
133 - Tall Shrub 18	
134 - Tall Shrub 19	
135 - Tall Shrub 20	
136 - Tall Shrub 21	
137 - Tall Shrub 22	
138 - Tall Shrub 23	
139 - Tall Shrub 24	
140 - Tall Shrub 25	
141 - not used	
142 - Deciduous	
143 - Coniferous	

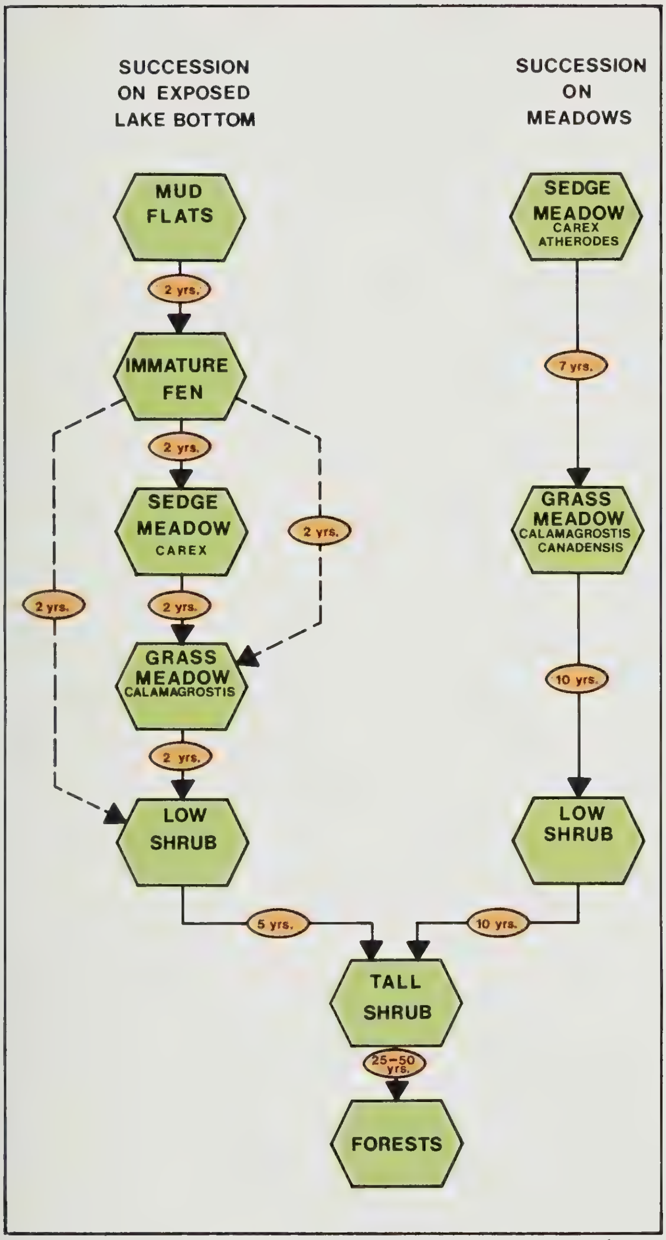


FIG. 4 Successional Trends expected under conditions of declining water levels

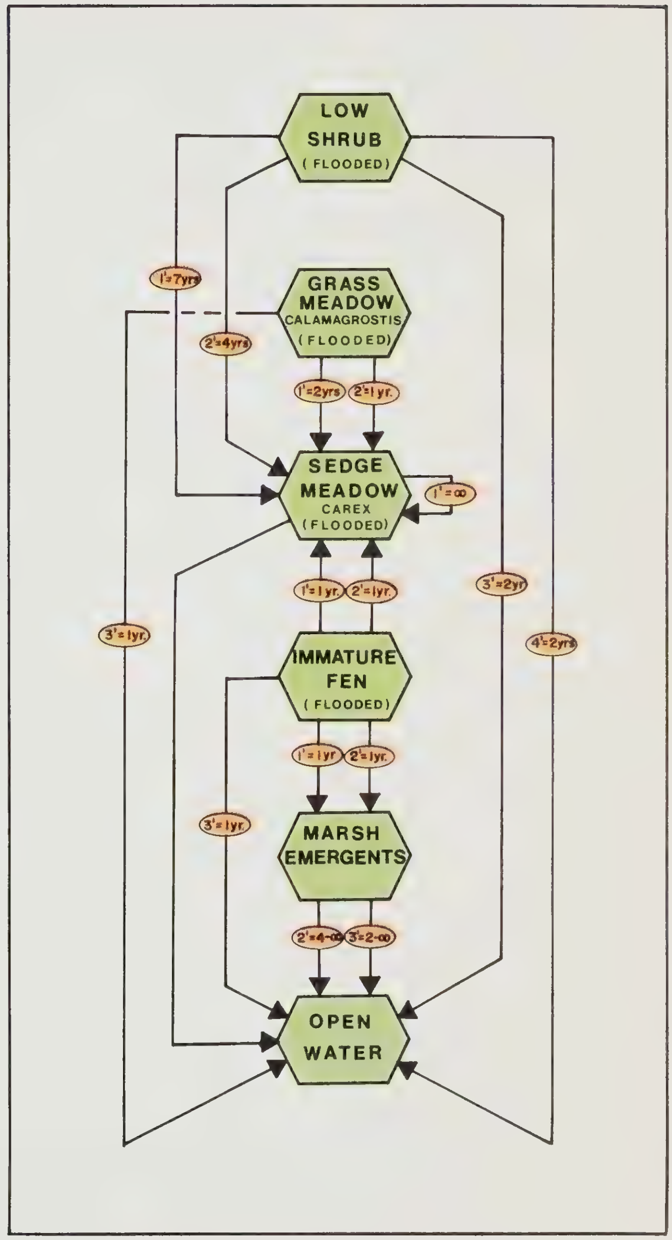


FIG. 5 Successional Trends expected under conditions of prolonged flooding

meadows established prior to 1968 follow the pattern serially from 151 through 177, and then transfer to 116 which is tall shrub, and proceed through 140. At the end of twenty-five years, tall shrub communities convert to deciduous forest (142). There is no link between deciduous forest and coniferous forest in the present model because this successional step would take many years to occur. Pre-1968 communities of Calamagrostis, low shrub and tall shrub follow the same advancing pattern as the sedge meadows, by advancing from the appropriate initial number.

The process of plant succession under conditions of prolonged flooding is considerably more complicated (Figure 5). Both depth of water and duration of flooding during the growing season have to be considered. When a habitat type becomes flooded, it is assigned one of the code numbers listed in Table 7. For example, if tall shrub is flooded by 1.5 feet of water, the habitat type is defined as number 215. If it remains flooded at that depth the following year, it becomes 214 and so on. If, in the following year, the water levels become 2.6 feet deep, the 214 becomes 314 and then drops down to number 312. Flooding of low shrub community is similar. If the flooding continues long enough to reach the end of the chain the shrub communities are considered dead and, depending on depth, Carex or open water then replaces them.

If flooded, deciduous forest and coniferous forest require only three years to kill (Table 7). A Calamagrostis community, when flooded for more than two years, dies out and becomes a Carex atherodes community. Carex atherodes, if flooded at greater than

Table 7. Coding used in plant succession portion of computer model for succession below water.

Tall Shrub 1.0-1.9' Deep	Tall Shrub 2.0-2.9' Deep	Tall Shrub 3.0-3.9' Deep
200 - T.S. dead, Carex emerg.	300 - T.S. Dead, Open water	400 - T.S. dead, Open water
201 - 1 yr. before dead	302 - 1 yr. before dead	404 - 1 yr. before dead
202 - 2 yr. before dead	304 - 2 yr. before dead	408 - 2 yr. before dead
203 - 3 yr. before dead	306 - 3 yr. before dead	412 - 3 yr. before dead
204 - 4 yr. before dead	308 - 4 yr. before dead	
205 - 5 yr. before dead	310 - 5 yr. before dead	
206 - 6 yr. before dead	312 - 6 yr. before dead	
207 - 7 yr. before dead	314 - 7 yr. before dead	
208 - 8 yr. before dead		for 4.0-4.9'
209 - 9 yr. before dead		405 - 1 yr. before dead
210 - 10 yr. before dead		410 - 2 yr. before dead
211 - 11 yr. before dead		
212 - 12 yr. before dead		
213 - 13 yr. before dead		
214 - 14 yr. before dead		
215 - 15 yr. before dead		

Low Shrub 1.0-1.9' Deep	Low Shrub 2.0-2.9' Deep	Low Shrub 3.0-4.9' Deep
500 - L. S. Dead, Carex emerg.	600 - L. S. Dead, Open water	700 - L. S. Dead, Open Water
501 - 1 yr. before dead	601 - 1 yr. before dead	701 - 1 yr. before dead
502 - 2 yr. before dead	602 - 2 yr. before dead	702 - 2 yr. before dead
503 - 3 yr. before dead	603 - 3 yr. before dead	702 - 3 yr. before dead
504 - 4 yr. before dead	604 - 4 yr. before dead	
505 - 5 yr. before dead		
506 - 6 yr. before dead		
507 - 7 yr. before dead		

(Continued on next page.)

Table 7. Continued.

Carex atherodes 2.0-2.9' Deep

800 - Open water
801 - 1 yr. before dead
802 - 2 yr. before dead
803 - 3 yr. before dead
804 - 4 yr. before dead
805 - 5 yr. before dead
806 - 6 yr. before dead
807 - 7 yr. before dead

0.0-1.9' Deep - no change
over 3.0' Deep - open water

Calamagrostis 2.0-2.9' Deep

900 - not used, Cala
goes to Carex
901 - 1 yr. before Carex
902 - 2 yr. before Carex

0.0-1.9' Deep - no change
over 3.0' Deep-open water

Immature fen 2.0-2.9'Deep

1000 - open water
1001 - 1 yr. before dead
1002 - 2 yr. before dead
1003 - 3 yr. before dead
1004 - 4 yr. before dead

0.0-1.9' Deep - no change
3.0-3.9' Deep - decrease
by 2 yr.
4.0-4.9' Deep - decrease
by 3 yr.

Emergents 2.0-2.9' Deep

1100 - open water
1101 - 1 yr. before dead
1102 - 2 yr. before dead
1103 - 3 yr. before dead
1104 - 4 yr. before dead
1105 - 5 yr. before dead
1106 - 6 yr. before dead
1107 - 7 yr. before dead
1108 - 8 yr. before dead
1109 - 9 yr. before dead
1110 - 10 yr. before dead
1111 - 11 yr. before dead

0.0-1.9' Deep - no change
3.0-3.9' Deep - decrease by 2 yr.
4.0-4.9' Deep - decrease by 3 yr.

Deciduous forest

1200 - open water
1201 - 1 yr. before dead
1202 - 2 yr. before dead
1203 - 3 yr. before dead

1' Deep - Decrease by 1 yr.
2' Deep - Decrease by 2 yr.
3' Deep - Decrease by 3 yr.
4' Deep - Decrease by 4 yr.

Coniferous forest

1300 - open water
1301 - 1 yr. before dead
1302 - 2 yr. before dead
1303 - 3 yr. before dead

1' Deep - see Deciduous
2' Deep - see Deciduous
3' Deep - see Deciduous
4' Deep - see Deciduous

two feet for over seven years, reverts to open water. Immature fen communities require only four years to be killed at depths two feet and over. Established emergents such as bulrushes, *Phragmites*, etc. withstand flooding for considerable lengths of time and require over eleven years at depths of between two to three feet before they revert to open water. A greater depth of flooding on each of these communities increases the rate of killing and, in general, depths of less than one foot maintain the flooded community unchanged.

In actual operation within the model, water fluctuations from year to year can shift the community from a flooded condition to a terrestrial one and back, thus maintaining a more or less steady state by advancing and retarding plant succession. This is what has occurred naturally on the Delta, and if these alternating high and low water years are introduced into the model, succession can be seen to be more or less "controlled". However, if the water levels are dropped for a number of years, terrestrial succession advances, and the converse occurs if the water levels are maintained at a high level for a number of years.

SIMULATING MUSKRAT POPULATIONS AND CARRYING CAPACITY

The model accepts the fall 1971 populations of muskrats as the starting populations for each subdivision as follows:

Subdivision	Muskrats
A	1,000
B	9,200
C	1,500
D	400
E	200
F	15,000
G	2,300
H	1,800
I-J	1,700
K	3,200

The sex ratio was assumed to be 1 to 1. The model uses optimum production from spring to fall of 14 young per female or 7 young per adult. Rising water levels during time periods 1, 2 and 3 reduce the optimum production as follows:

Increasing Water Levels	Young Muskrat Mortality Rate
Less than 1.0 Feet	0%
1.0-1.9 Feet	7.5%
2.0-2.9 Feet	15%
3.0-3.9 Feet	30%
4.0 Feet +	50%

Normal summer mortality of adults is 5 percent of the population and this occurs just prior to the breeding season. Although a rise in water levels during time periods 1, 2 and 3 can cause a reduction in production, the water depth *per se* in summer is

unimportant to the growth of the population, unless there is no water at all. If, during the summer, the entire subdivision is dry, then the population reduces to a minimum value of 200 animals composed of 100 ycung and 100 adults.

The fall population is the sum of the young muskrats remaining plus the adults. The winter population is governed by the carrying capacity for muskrats over winter. This is determined by the number of acres of emergents flooded to certain depths. Optimum carrying capacity is defined as 10 muskrats per acre of emergents. Winter mortality occurs in all muskrat populations, and in calculating the carrying capacity for the marsh over winter, the following is the percentage survival:

Water Depth	Percentage Survival
0.6 - 1.0	30
1.1 - 2.0	40
2.1 - 3.0	50
3.1 +	70

Flooded areas less than 0.6 feet deep were not considered to be capable of over-wintering muskrats.

The simulated number of muskrats surviving the winter is calculated by allocating the fall population to the available emergent habitat to a maximum of 10 animals per acre. In the allocation procedure, the best or deepest habitat is occupied first and then the process is continued down to the shallowest. The fall population is then reduced by using the appropriate survival values. The resulting population segments are added

together, the sum is tested to see if it exceeds the total carrying capacity for the subdivision, is equated to the carrying capacity if it does exceed it, and is then stored as the number of animals surviving until March of the following year.

Trapping can be simulated in the model if desired. If trapping is specified, it is assumed to occur in the spring, acting upon the March population and reducing it by 50 percent just prior to the breeding period. Simulated trapping was kept relatively simple and density independent because not enough knowledge was available to assign a density dependent relationship to trapping rate.

SIMULATING BISON POPULATIONS AND CARRYING CAPACITY

The program reads in the following 1971 bison populations:

Subdivision	Number of Bison
D	0
G	500
H	1,500
I-J	7,000
K	200

In the subdivisions of the Delta outside of the Wood Buffalo National Park the bison population is negligible.

Population growth was kept very simple, at a rate of 4 percent per year, because of the lack of information relating population growth to water levels. The main purpose of including it in the

model is to provide a comparison between the herd size and the potential herd size as expressed by carrying capacity.

The carrying capacity is calculated for winter by using the number of acres of forage available above water in each habitat type. The only habitat considered forage when flooded is sedge meadow inundated to a maximum depth of one foot. The number of animal units each habitat type was capable of supporting is given in Table 4, Appendix M. Total animal units were summed for each subdivision to produce the carrying capacity for that year.

SIMULATING MOOSE POPULATIONS AND CARRYING CAPACITY

The 1971 moose populations are read into the model as follows:

Subdivision	Numbers of Moose
A	10
B	100
C	25
D	5
E	5
F	100
G	100
H	100
I-J	50
K	100

The moose population is considered to grow at a constant rate of 2 percent annually. Water levels do not have any direct effect on the moose population but they indirectly affect the carrying capacity. The main reason for including the moose population in

the model was to compare it with the potential population as expressed by carrying capacity.

The carrying capacity is the product of the number of acres of the various habitat types times the rating that is given to each habitat type as defined in Table 4, Appendix N. The model accepts all suitable habitat on the Delta, whether flooded or not, since moose are browsers and there is food available even in flooded shrub habitat. Both population and carrying capacity are printed for each subdivision each year.

SIMULATING WATERFOWL PRODUCTION AND STAGING

The following production densities per mile of shoreline habitat were used as input to the waterfowl model (from Figures 2 and 3, Appendix K):

Shoreline Type	Dabblers	Divers
Mud flats	24.9	0.0
Immature fen	27.9	8.3
Meadow	48.9	19.3
Low Shrub	27.9	31.9
Tall Shrub	36.0	42.4
Deciduous	16.8	38.5
Coniferous	9.9	34.1
Rock Outcrop	2.7	0.0

These population densities are near optimum because they were determined during a year in which flooding during the breeding season was minimal and they reflect production on basins which held water throughout the nesting and rearing season. Less than

optimum production could be expected under conditions of fluctuating water levels during time periods 1 and 2 and the following limiting conditions were applied:

Increasing Water Levels	Survival Rate
Less than 0.5 Feet	100%
0.5 - 0.9 Feet	75%
1.0 - 1.9 Feet	50%
2.0 Feet +	0%

Decreasing Water Levels	Survival Rate
Less than 1.0 Feet	100%
Greater than 1.0 Feet	75%

It was necessary to relate waterfowl production to length of shoreline rather than area of habitat, and the procedure given under 'SIMULATING HYDROLOGIC PROCESSES' was used to determine the total length of shoreline available for nesting waterfowl at the beginning of time period 1 each year. However, no clearcut method was available for determining what habitat types would comprise the shoreline under changing water levels each year. The problem occurs because, under actual conditions on the Delta, there are several hundred perched basins comprising a variety of shoreline habitat types at any one time, whereas in the model there are only eight perched basins permissible per subdivision and only one shoreline habitat type permitted per perched basin during any period of time.

In order to approximate the natural situation, the following procedure for determining the "average" shoreline habitat

condition on each perched basin was used. First, an initial ratio relationship between area and shoreline length of each habitat type was calculated for the 1970 conditions for non-flooded habitat types. It is assumed that this ratio relationship continues to hold following changes in water levels; that is, the length of shoreline available for each habitat type is proportional to the non-flooded area of that habitat type. For each year, the model totals the number of acres of each habitat type above water, converts using the acre:mile ratios to shoreline length, and expresses each habitat length as a percentage of the sum of all. Waterfowl densities for each shoreline habitat type are then applied to the percentages to give a weighted average value per mile of shoreline.

A further refinement was considered necessary for dabblers because their presence along a shoreline is influenced by one or more habitat types back from the actual shoreline where they build their nests. For each perched basin, the model determines the habitat type where the current water line rests. This habitat type is given a proximity rating of 10. The adjacent habitat type further up the landscape is assigned a proximity rating of 4, and all of the remaining habitat types above this one are assigned a rating of 1. These weighting factors are applied to the appropriate habitat density values calculated above, and each expressed as a percentage of the sum of all. Each habitat density percentage is then multiplied by the total shore miles available as determined in the section SIMULATING

HYDROLOGIC PROCESSES, and the results are totalled.

For calculation cf diver productivity, the model uses the habitat type existing at the shoreline edge because diving ducks nest either in emergents or along the immediate edge of the basin.

Numbers of fall-staging waterfowl were believed to be too variable to express in terms of birds per habitat acre because the birds often crowd into small areas and because habitat elsewhere, or weather patterns, affect concentrations and duration of stay on the Delta. It was decided therefore to concentrate on quantifying fall-staging habitat only in order to perceive some measure of attractiveness under various water regimes. Fall-staging habitat was defined as the sum of acres of mud flat and first-year immature fen existing in time period 4.

SIMULATING MANAGEMENT OF WILDLIFE RESOURCES

One of the objectives of the Delta Project study was to determine water level regimes that would be most suitable for maximizing wildlife production. This aspect was never fully explored, mainly because, as the study progressed, the emphasis changed to the consideration of restoration of the Delta to natural conditions. Within National Park boundaries, the goal is to maintain natural conditions wherever possible. In other parts of the Delta, however, management of wildlife resources can be undertaken, and the simulation model can be used as a technique to determine best water level regimes for various forms of wildlife and their habitat.

A number of computer model runs were made on one or more subdivisions to test the effects of water-level changes on wildlife populations. Figure 6 illustrates the relationship of length of perched basin shoreline to water levels. It demonstrates the importance of periodic flooding to maintaining shoreline conditions vital to wildlife production and ecological diversity. If Lake Athabasca levels are held high, as during Years 2 through 5, shoreline length is decreased because many small basins combine into a few large basins. A return to lower lake levels (Year 6) causes surrounding perched basins to separate into individual basins once more, and total shoreline distance increases substantially. Evaporation and seepage occur every year, and during Years 6 through 9 the basins gradually recede, reducing total shoreline length. During the summer of Year 10 flooding occurs again, filling most basins, thus

increasing shoreline length during Year 11. Given no significant flooding after that, shoreline length gradually decreases in Years 12 through 15.

Figure 7 depicts the relationship between water levels and plant succession in the Claire-Mamawi complex (IJ) of the Delta, as produced by the computer run of the previous example. Approximately 38,000 acres of emergents are available in Year 1, but this increases greatly in Years 2 through 5 because of flooding, mainly at the expense of sedge and grass meadow habitats which become inundated during these flood years. When water in Lake Athabasca is lowered during Years 6 through 9 the meadows have decreased in area compared to Year 1, because some have died out and become open water or exposed mud flat in Year 6. Plant succession gradually converts immature fen in Years 6 and 7 to meadow in Year 8, and emergents are disappearing slowly as the vegetation in the perched basins becomes stranded due to evaporation and lack of refilling by flood waters. Shrub habitat gradually increases during this sequence of years.

It is confirmed from this example and other program runs that the presence of any given combination of habitat types on the Delta is only temporary. Plant distribution changes with time because plant succession is controlled to a large extent by past and present water level events on the Delta. While water levels on Lake Athabasca appear to be largely independent of each other between years, the same is, of course, not true for plant distribution. For example, low water levels for several summers in a row can turn portions of exposed marsh bottom into a

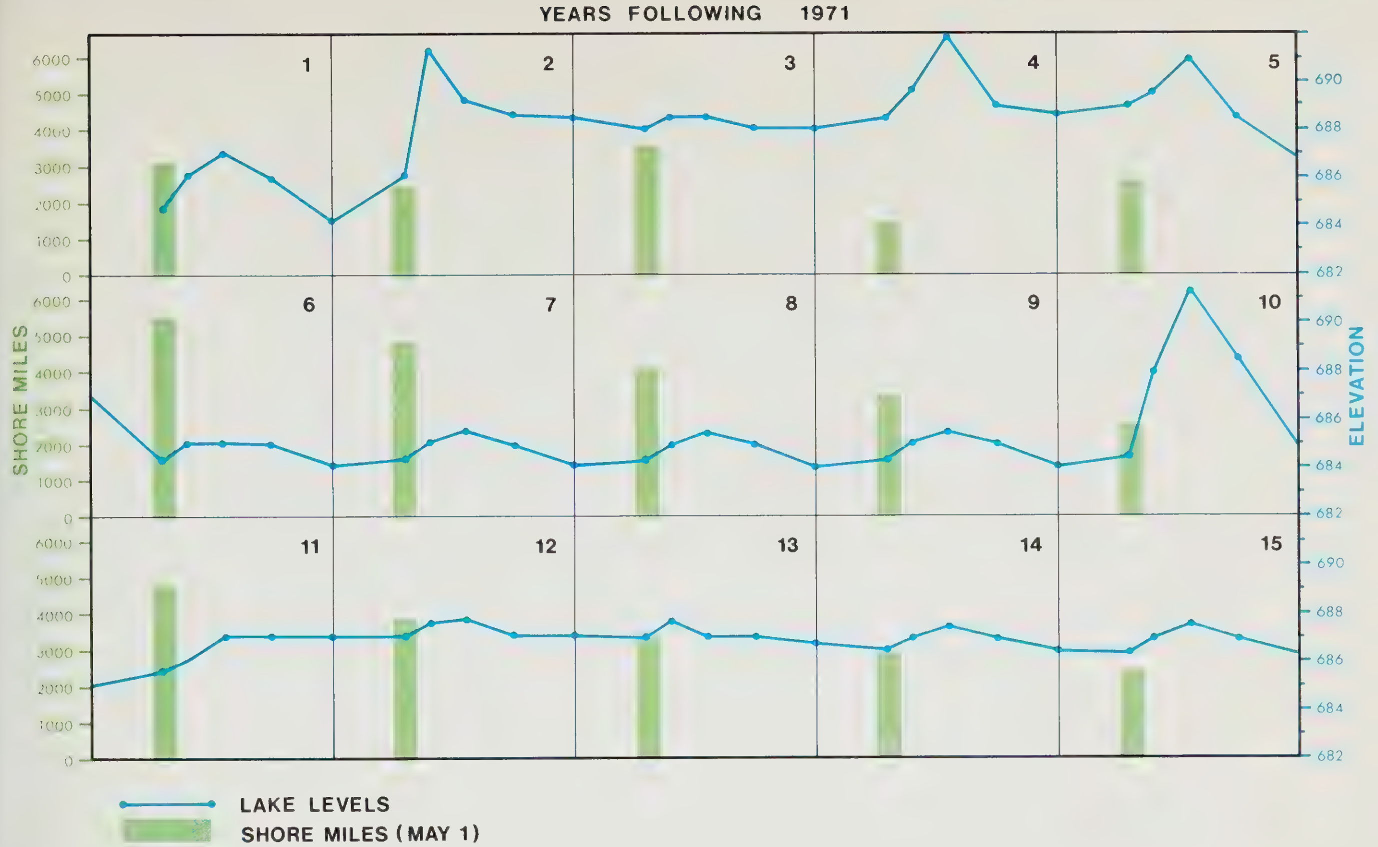


FIG. 6 Length of Perched Basin Shoreline in relation to water levels in the Claire-Mamawi complex

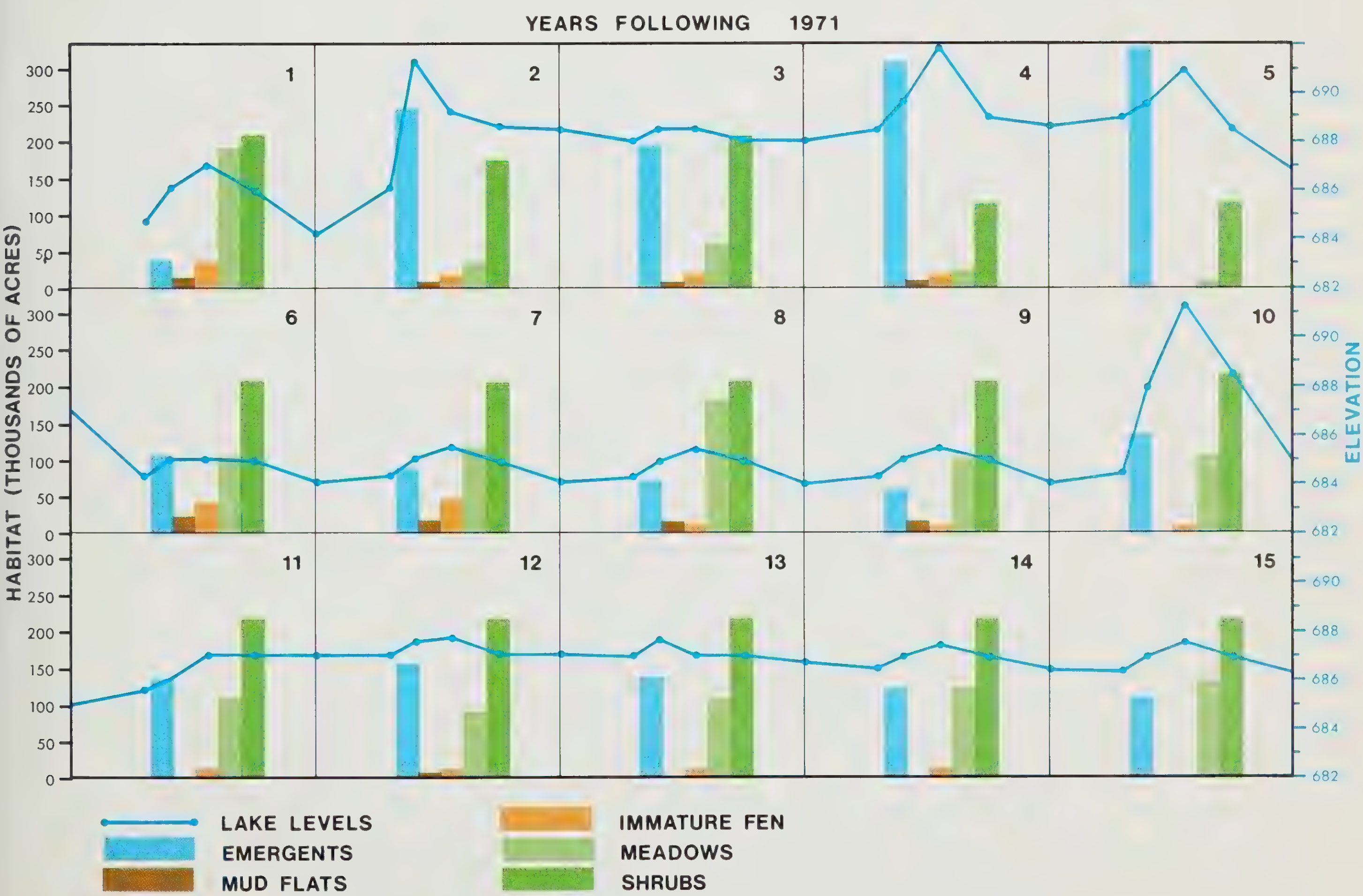


FIG. 7 Amount of Habitat in relation to water levels in the Claire-Mamawi complex

vegetated community which may persist for years. Therefore, because many of the ecological events are serially correlated with the past it was often necessary to make several computer runs to get "average" results, beginning the sequence with high years on one run, low years on another, and average years on a third. This was one way of assessing impact of possible future water levels on the Delta.

WATERFOWL

Figure 8 shows the projected relationship of water levels in the Claire-Mamawi complex to waterfowl habitat and numbers, using the computer model. Production is influenced by both the amount of shoreline present on May 1 and the changes in water levels occurring during the nesting season, May 1 through June 30. During the first five years the number of ducks produced compared with the number of shore miles available is fairly small because of large water level fluctuations during the nesting season. During Years 6 through 9 production compares favorably with shore miles, indicating high nesting success under fairly constant summer water levels. During Years 11 to 15, production is seen to gradually decline as the shore miles disappear because of lack cf reflooding.

Fall-staging waterfowl habitat is seen to be a function of water levels and stage of plant succession (Figure 8, green bar graph each year). Preferred habitat, defined as either mud flat or immature fen, is used mainly by dabblers and geese to feed and rest. As expected, during high water years, this type of habitat

is greatly reduced, but during low water years preceded by high ones, an abundance of mud flat exists (see Year 6). During years when very little water fluctuation occurs, few mud flats are exposed and the amount of habitat for fall-staging waterfowl declines.

Management of the Delta to increase waterfowl production would stress the avoid the increase of water levels significantly during time periods 1 and 2. The perched basins which appear to require reflooding at intervals of three to five years would have to be filled during some other time period, perhaps during fall. High water levels during fall would not be optimum for holding large concentrations of migrant birds. However, under a compartmentation system, certain areas could be left with low water levels, thus attracting fall migrants. Under any kind of a management scheme, vegetation succession would have to be monitored so that undesirable changes in plant communities would not occur.

MUSKRATS

Figure 9 presents results of one run on the Claire-Mamawi complex, using the same water levels as the previous examples and showing muskrat overwinter carrying capacity (bar graph) and the muskrat population each year (red line). The population begins at a very low level, starting in 1971, and grows slowly at first, even while experiencing optimum winter conditions. Thus, in Years 2 through 5 there is much more habitat available in the form of emergent vegetation than required for the

FIG. 8 Waterfowl Habitat and Production in response to lake levels in the Claire-Mamawi complex

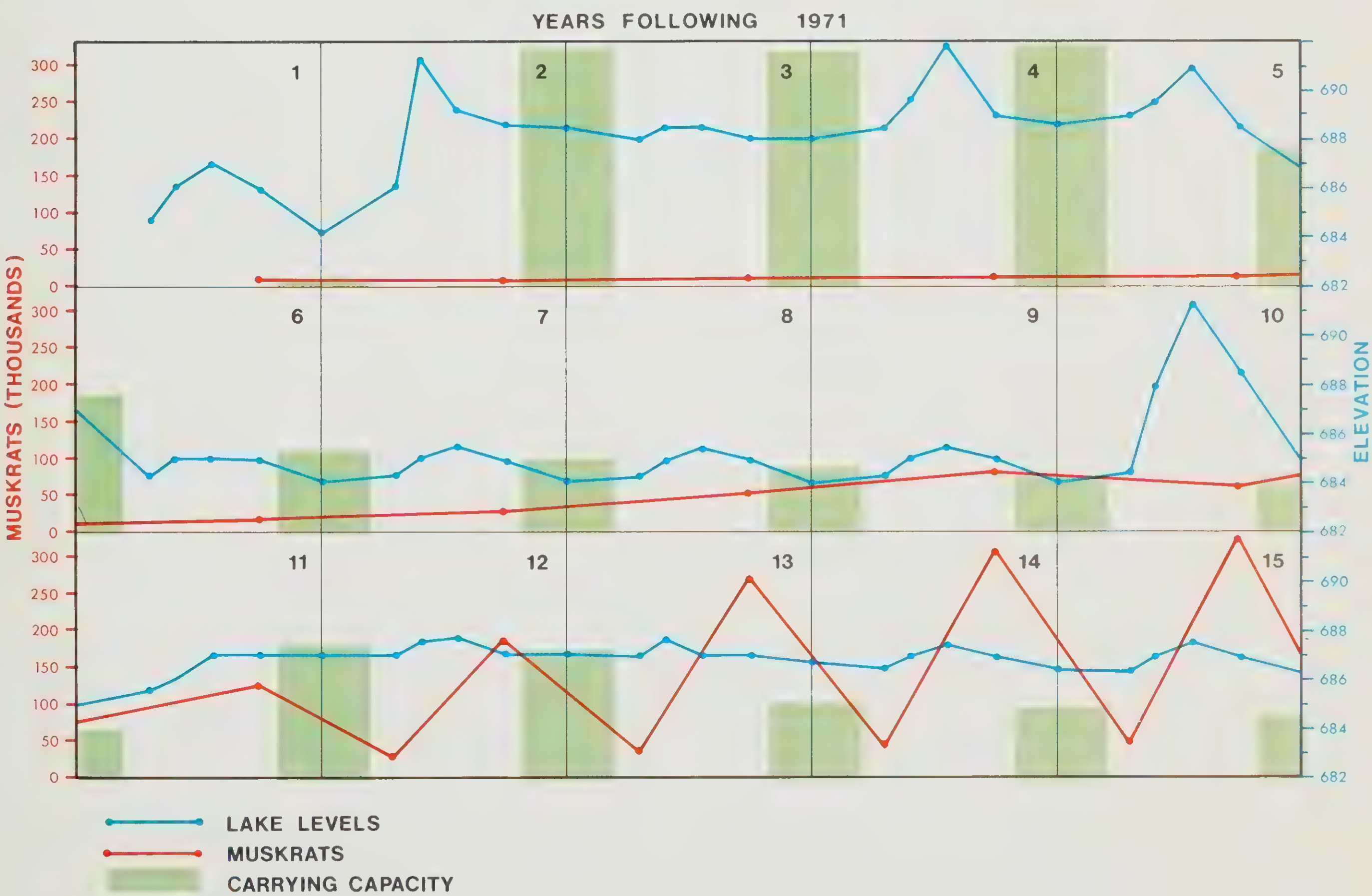


FIG. 9 Muskrat Carrying Capacity and Population in response to water levels in the Claire-Mamawi complex

expanding population. As winter water levels decline during Years 6 through 10, the amount of habitat that can support muskrats declines also (lower bar graphs), but the population still is generally below the carrying capacity. Following Year 10 when most perched basins are refilled, and in Years 11 through 12, the higher winter levels support greater numbers of muskrats and the population continues to grow. After Year 12 a substantial mortality occurs over winter due to reduced carrying capacity, and even though the population is still on the increase, the rate of increase is declining. Population growth in this example was based on an assumption of three years without trapping followed by trapping after Year 3.

Critical to the success of muskrat is sufficient depth in the perched marshes and ponds to allow winter survival of the animals. Also important is the need to maintain suitable vigorous growth of emergent cover, which implies reducing water levels during the growing season so that maximum growth of emergent plants can be achieved. Water levels on managed marshes could then be increased to safe depths as fall approaches.

Periodic drawdowns on the marsh might become necessary if vegetation deteriorates over a period of years. Under a compartmentation system, drawdowns could be rotated from compartment to compartment so that a good portion of the Delta would be producing muskrats each year.

It is evident from several runs of the computer model, that with proper development and management of the marsh, populations of

muskrats could be achieved well in excess of historical numbers. Such development however, would be costly in terms of dikes, dams and perhaps pumping, and would have to be confined to areas outside of the National Park.

BISON

The computer model calculated carrying capacity of bison on the Delta only for the winter period, and is based on the amount of forage above water in each habitat type (Figure 10, bar graph). It does not take into account forage unavailable due to snow cover, and therefore probably overestimates the figure. The model also includes population growth of the herd.

Carrying capacity, of course, varies from year to year, based on the amount of non-flooded habitat and upon successional stages. Thus, during years of extreme flooding, the available summer range for bison could be severely reduced, and bison would be forced to graze heavily at the higher elevations or else migrate to other parts of the Park.

The perpetuation of vast grass and sedge meadows on the Delta is due to periodic flooding during summer which prevents willow encroachment. A permanent trend toward more stable water levels of Lake Athabasca would consequently bring about a reduction in the amount of grass and sedge habitat on the Delta. This would eventually lead to a reduction in the bison herd on the Delta.

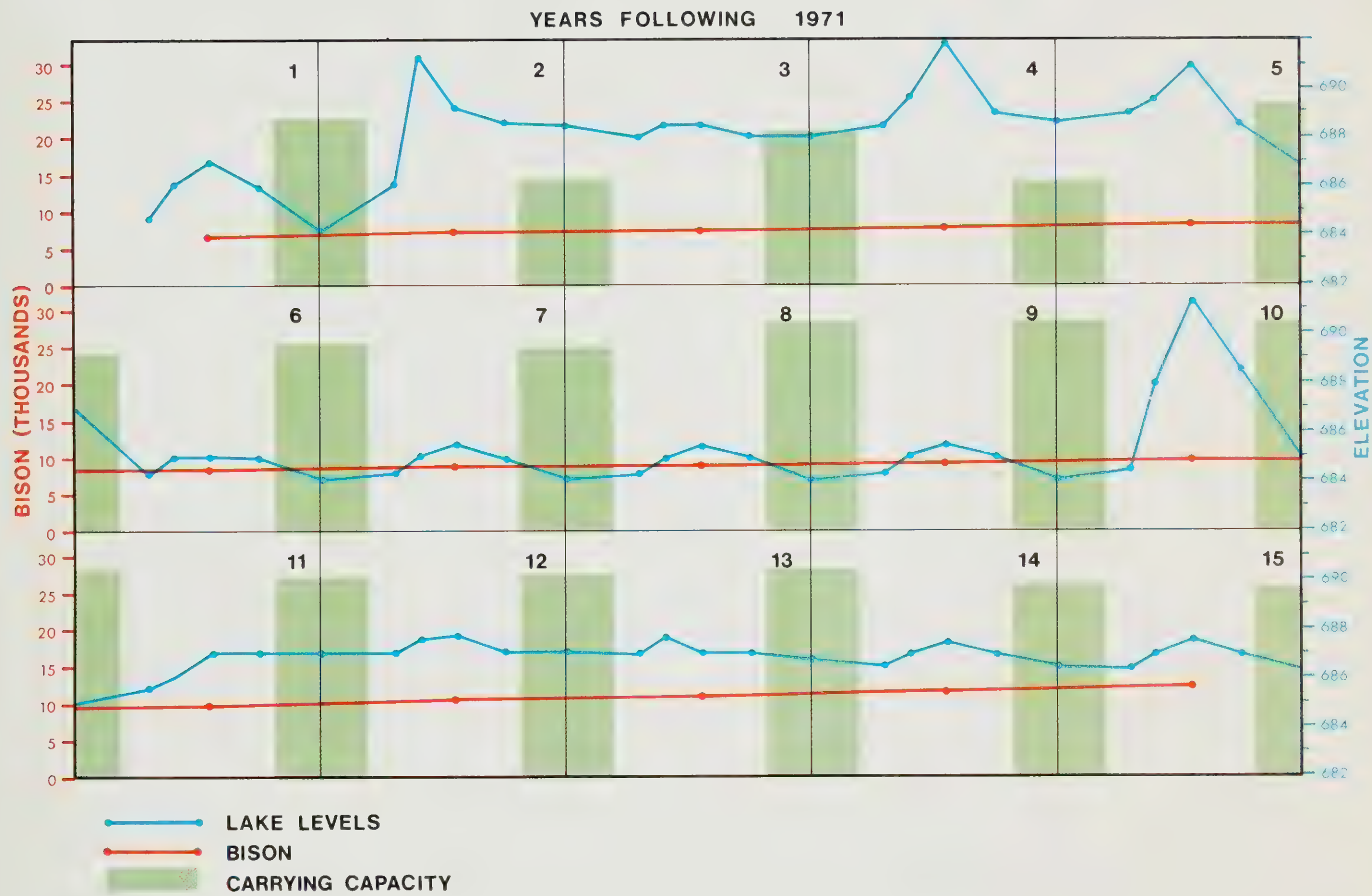


FIG. 10 Bison carrying Capacity and Population, related to water levels in the Claire-Mamawi complex

MOOSE

From the model runs, the carrying capacity for moose on the Delta fluctuates between approximately 3,500 and 4,000 animals. Water level changes do not seem to change the values significantly. With an initial starting population of approximately 600 animals, the population is well below the carrying capacity. Management techniques other than water level manipulation are required if it is desired to significantly increase the moose population.

COMPARING NATURAL AND MODIFIED WATER REGIMES

One of the purposes of the wildlife model was to determine whether or not future operation of the Bennett Dam would change the water regime of the Delta sufficiently enough to affect the production of major wildlife species. In other words, what is the predicted long-term impact of the modified regime on the future wildlife resources of the Delta? The hydrology simulation model provided an indication of how the Bennett Dam would have altered Lake Athabasca water levels during the 12-year period 1960-71 if the dam had been in operation during this period (Volume 1, Appendix E). This was the only period of record from which this type of comparison could be made, because, although water level records extending back 35 years are available, data on flows required for this analysis are not complete before 1960.

In order to use the model in a predictive way, the simulated Lake Athabasca levels from the 1960-71 record were adapted for input to the wildlife model. It is not possible to predict future water level events for any specific year or group of years. However, using the past as a guide, it is possible to assign probabilities to occurrences of particular ranges of water levels on Lake Athabasca. The 35-year record from 1935-71 was considered typical of past conditions, since a number of parameters of this record agree fairly closely with those of the 157-year record derived from tree-ring analysis (Volume 1, Appendix P). Within the 35-year record there are periods of low-water years and periods of high-water years along with average

years. Since this 35-year record is more representative of what is likely to happen on Lake Athabasca than is the 12-year record beginning in 1960, it was highly desirable to use it as the pool from which individual years were chosen for the simulation run.

As a group, the 12 years represent higher than average levels, although one or two years approach average conditions. Therefore, in making up sequences of water level events for the wildlife model, the 35-year record was used as the basis for frequency of occurrence of average, below average, and above average years, while the actual pairs of yearly graphs were drawn from the 12-year pocl, with each year chosen being the one that most closely approximated the selected year in the 35-year record. Table 8 gives the years selected to represent the 35 year record.

To convert water levels for input to the simulation model, five-day means from the simulated hydrographs were grouped into the ecological time periods and the average water level for each time period was computed. Then the peak five-day level for each year was determined and this value replaced the average level of the time period in which the annual peak level occurred. This substitution was necessary to simulate more accurately the flooding of all perched basins within range of the flood peak. Table 9 presents the adjusted simulated natural levels and Table 10 gives the modified levels resulting from simulated operation of the Bennett Dam. These were pools from which individual years were chosen to make up input for runs of the wildlife model.

Table 8. Years chosen from the 12-year pool to represent the 35-year record.

Actual Year	Year Chosen	Actual Year	Year Chosen
1937	1968	1955	1968
1938	1970	1956	1970
1939	1970	1957	1970
1940	1969	1958	1968
1941	1970	1959	1969
1942	1968	1960	1960
1943	1968	1961	1961
1944	1970	1962	1962
1945	1969	1963	1963
1946	1970	1964	1964
1947	1969	1965	1965
1948	1971	1966	1966
1949	1970	1967	1967
1950	1970	1968	1968
1951	1969	1969	1969
1952	1970	1970	1970
1953	1970	1971	1971
1954	1967		

Table 9. Simulated water levels of natural regime, from which individual years were chosen to make program runs.

Year	Ecological Time Period				
	1	2	3	4	5
1960	682.7	685.5	689.2	688.3	685.8
1961	685.9	688.3	689.1	686.3	682.1
1962	683.7	686.8	690.1	689.1	684.8
1963	686.5	688.8	689.4	687.3	683.2
1964	683.5	686.7	689.5	690.0	685.6
1965	686.5	688.9	691.4	689.2	684.9
1966	685.6	687.9	689.2	688.4	684.2
1967	684.9	688.6	690.4	688.1	683.5
1968	683.5	686.4	688.7	686.7	683.9
1969	685.7	687.4	686.4	684.5	682.1
1970	683.3	685.4	687.3	685.2	683.0
1971	683.6	686.0	690.0	687.4	682.1

Table 10. Simulated water levels of modified regime (Bennett Dam in operation), from which individual years were chosen to make program runs.

Year	Ecological Time Period				
	1	2	3	4	5
1960	683.9	685.4	686.9	686.6	685.7
1961	687.3	687.0	686.4	685.0	682.6
1962	685.5	687.4	688.3	687.7	684.8
1963	687.4	688.4	687.5	686.1	683.5
1964	685.2	686.3	686.2	686.7	685.2
1965	687.7	688.6	689.3	687.9	685.2
1966	687.0	688.0	687.5	687.0	684.5
1967	686.6	688.5	688.1	686.8	683.9
1968	685.4	868.0	686.8	685.5	684.2
1969	687.6	687.2	685.9	684.2	682.5
1970	684.1	684.1	684.4	683.3	682.7
1971	684.6	685.4	687.9	686.0	683.9

Evaluation of changes resulting from operation of the Bennett Dam involved making comparative runs of the model for both the natural and the modified condition, using identical sequences of years. Nine comparative runs were assembled to simulate a number of possible combinations of water level events for the future (Table 11). Appendix 1 contains the water level input used for each run, and Appendix 2 includes the average annual production of various wildlife resources resulting from these regimes. Comparative Run E, a random selection of 35 years, was chosen for illustration, and subsequent graphs used in this paper of the wildlife production result from these hydrographs (Figure 11).

Under the modified regime that results from full operation of the Bennett Dam, fewer of the perched basins will be filled as often as they were in the past (Figure 12). Shore miles of perched basins on the Delta are expected to decrease by approximately 50 percent (Table 12). Water levels in these basins will undergo more frequent and greater reduction due to evaporation and transpiration. This will cause plant succession to proceed uninterrupted for longer stretches of time and will, for example, allow willow communities to become better established before the reflooding cycle repeats itself. The net effect will be that these portions of the Delta will age more rapidly than they would under natural conditions.

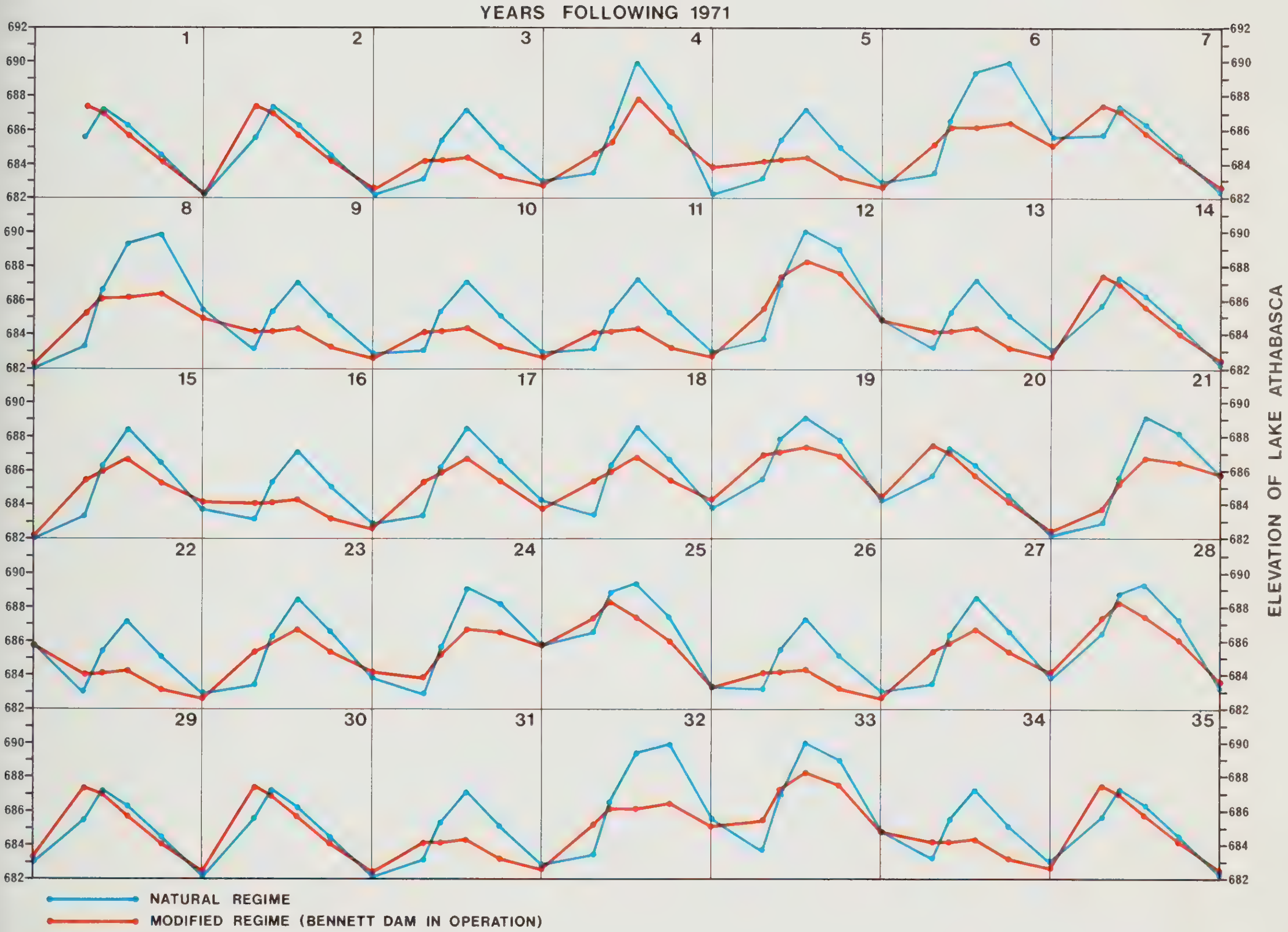
The reduction in midsummer flooding under the modified regime will improve hatching success on the Delta, but the reduction in frequency of refilling the perched basins and its effect on

Table 11. Listing of wildlife simulation program runs.*

GROUP RUN COMPRISED OF:
1. Natural Regime
2. Modified Regime (Bennett Dam in operation)
3. Proposed Rochers River Weir
4. Proposed Rochers River Constriction
5. Proposed Slave River Constriction

GROUP RUN	DESCRIPTION
A	35 years, repeating the 35 years in sequence from 1935-70, fluctuations of water levels within time periods on all experimental groups (Bennett Dam, Rochers Weir, etc.) the same as for Natural.
B	35 years, repeating the last 12 years (high years) three times, fluctuations of water levels within time periods on all experimental groups the same as for Natural.
C	35 years, repeating a low-water period of 12 years from 1948-59 three times, fluctuations of water levels within time periods on all experimental groups the same as for Natural.
D	35 years, rerun of "A", except using variable ranges in fluctuations of water levels within time periods most likely to occur in each experimental group.
E	35 years, random selection of years from 35-year pool of 1937-71, using best approximation of ranges in fluctuations of water levels within time periods.
F	35 years, repeating high years of 1960s first, then sequence from 1935 on, using best approximation of ranges in fluctuations of water levels within time periods.
G	70 years, rerun of group "F", then 35 additional years drawn at random from pool of 1937-71, using best approximation of fluctuations of water levels within time periods.
H	70 years, rerun of random group "E" plus an additional 35 years drawn at random from pool of 1935-71, using best approximation of fluctuations of water levels within time periods.
I	15 years, selected levels used for demonstration of the model output.
ICE	35 years, rerun of "A" with Bennett Dam regime water levels and simulating ice dam on Rochers River every 4, 5, 6 and 7 years.

*See Appendix 1 for water levels used.



11 Run E, 35 years of simulated Lake Athabasca water levels

Table 12. Shoreline miles of perched basins resulting from several simulation program runs comparing natural regime with modified regime.

Simulation Program Run	Mean Yearly May Shoreline in Miles Under Natural Regime	Decrease Due to Modified Regime
RUN D - 35 years	5,875	50%
RUN E - 35 years	5,669	51%
RUN F - 35 years	5,948	50%
RUN G - 70 years	5,581	53%
RUN H - 70 years	5,447	54%

shoreline length described above will reduce suitable edge for nesting waterfowl. Duck production is expected to decline by approximately 20-25 percent due to the modified regime (Figure 13, Table 13). Diver losses will be in the order of 3-22 percent, while dabbler production is expected to decrease by 25-30 percent.

Under the modified regime the bison population will not be affected immediately because the population is presently well below the carrying capacity of the Delta. However, the long-term trend will be a decline in the carrying capacity for bison because of accelerated plant succession which will occur in the meadows due to less frequent flooding. The results from the simulation runs do not indicate a significant long-term reduction in carrying capacity (Table 14). This is probably due to fairly high ratings given the shrub habitat which has understory of grasses and sedges. The change from meadow to shrub habitat, however, will be significant.

The average size of the muskrat population under the modified regime will be lower than in the past, but not as low as during the last four years. Reduction in population is predicted because of the reduced winter carrying capacity caused by generally shallower perched basins and marshes. Estimates of reduced carrying capacity range from 40-56 percent (Table 15). Decreases in the fall muskrat population are expected to range from 41 percent to as high as 66 percent under the modified regime compared with the natural regime (Table 15, Figure 14).

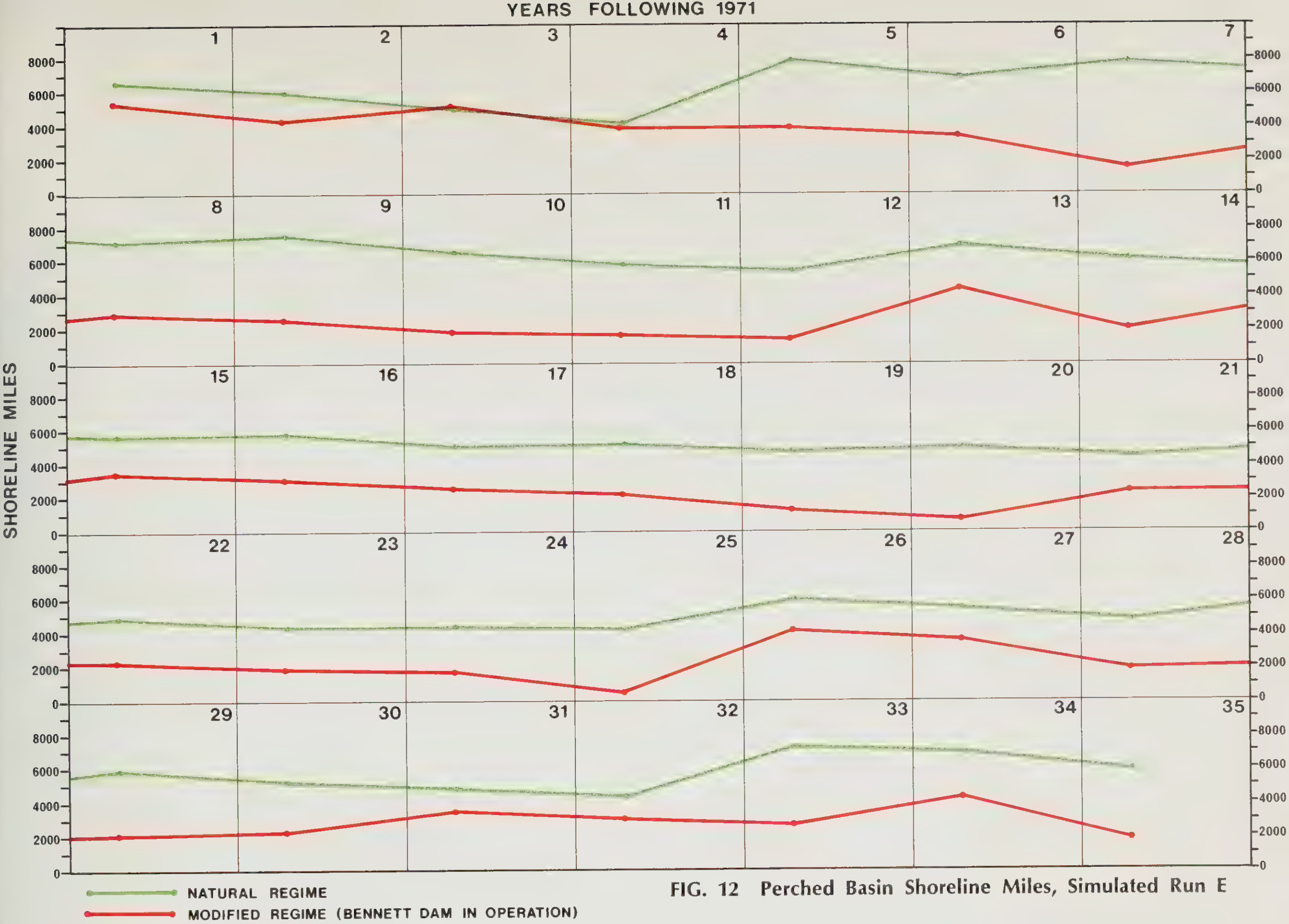


FIG. 12 Perched Basin Shoreline Miles, Simulated Run E

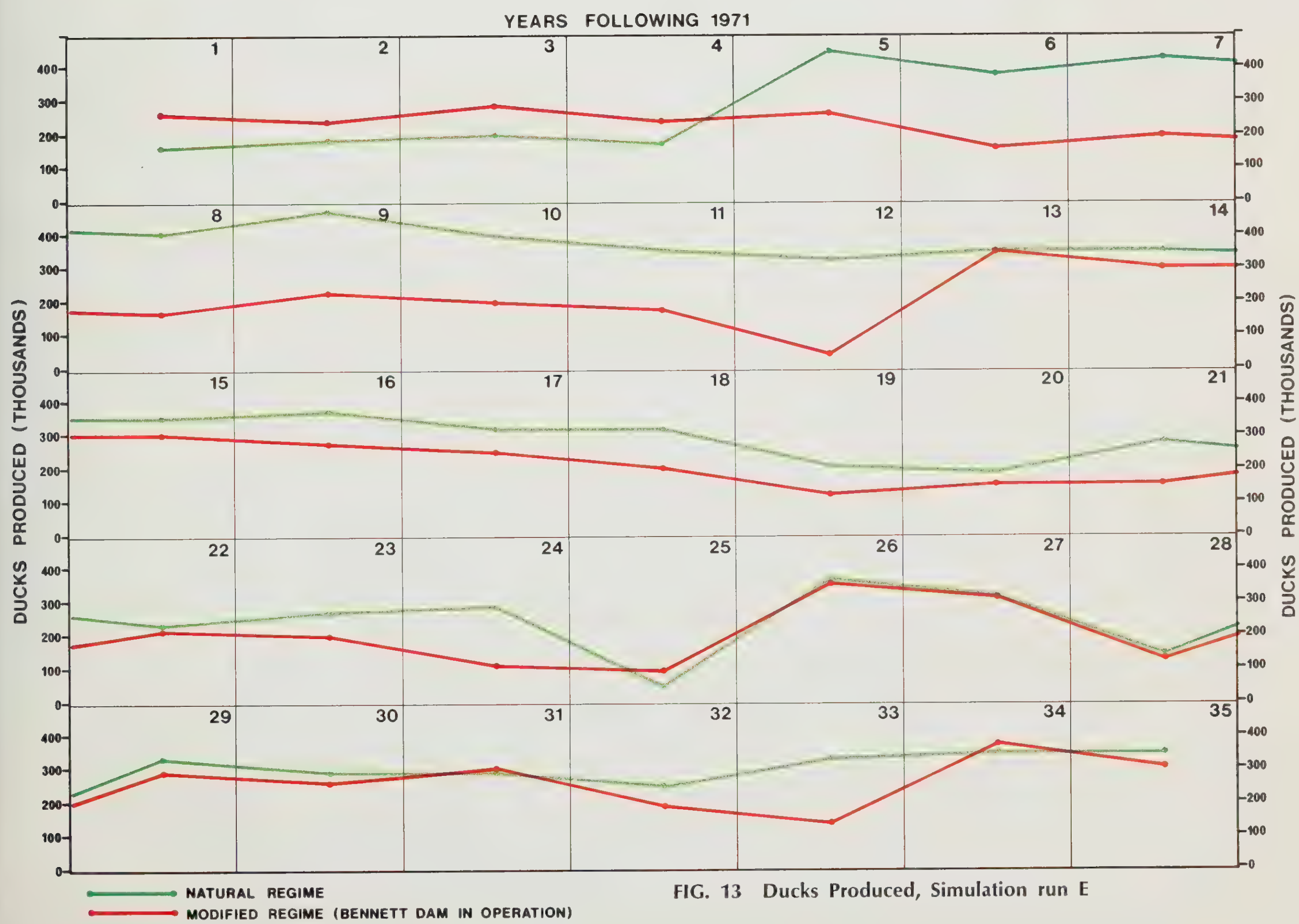


FIG. 13 Ducks Produced, Simulation run E

Table 13. Duck production resulting from several simulation program runs comparing natural regime with modified regime.

Simulation Program Run	Mean Yearly Ducks Produced Under Natural Regime	Decrease Due to Modified Regime
RUN D - 35 years	293,000	24%
RUN E - 35 years	303,000	26%
RUN F - 35 years	298,000	25%
RUN G - 70 years	277,000	19%
RUN H - 70 years	281,000	20%

Table 14. Over-winter carrying capacity for bison resulting from several simulation runs comparing natural regime with modified regime.

Simulation Program Run	Mean Yearly Carrying Capacity Under Natural Regime	Decrease Due to Modified Regime
RUN D - 35 years	25,900	4%
RUN E - 35 years	26,700	0%
RUN F - 35 years	27,300	4%
RUN G - 70 years	24,300	3%
RUN H - 70 years	24,500	0%

Table 15. Over-winter carrying capacity for muskrats, and fall muskrat populations, resulting from several simulation program runs comparing natural regime with modified regime.

Simulation Program Run	Mean Yearly Carrying Capacity Under Natural Regime	Decrease Due To Modified Regime
RUN D - 35 years	107,000	53%
RUN E - 35 years	159,000	50%
RUN F - 35 years	119,000	46%
RUN G - 70 years	95,000	42%
RUN H - 70 years	134,000	56%

Simulation Program Run	Mean Fall Muskrat Population Under Natural Regime	Decrease Due to Modified Regime
RUN D - 35 years	193,000	66%
RUN E - 35 years	265,000	56%
RUN F - 35 years	172,000	57%
RUN G - 70 years	184,000	41%
RUN H - 70 years	297,000	57%

The lower water levels of the modified regime will gradually improve habitat for moose because of their preference for the more advanced stages of plant succession. Estimated improvement in carrying capacity is approximately 17 percent (Table 16). This may or may not result in an increase in the population which now appears to be controlled by hunting pressure.

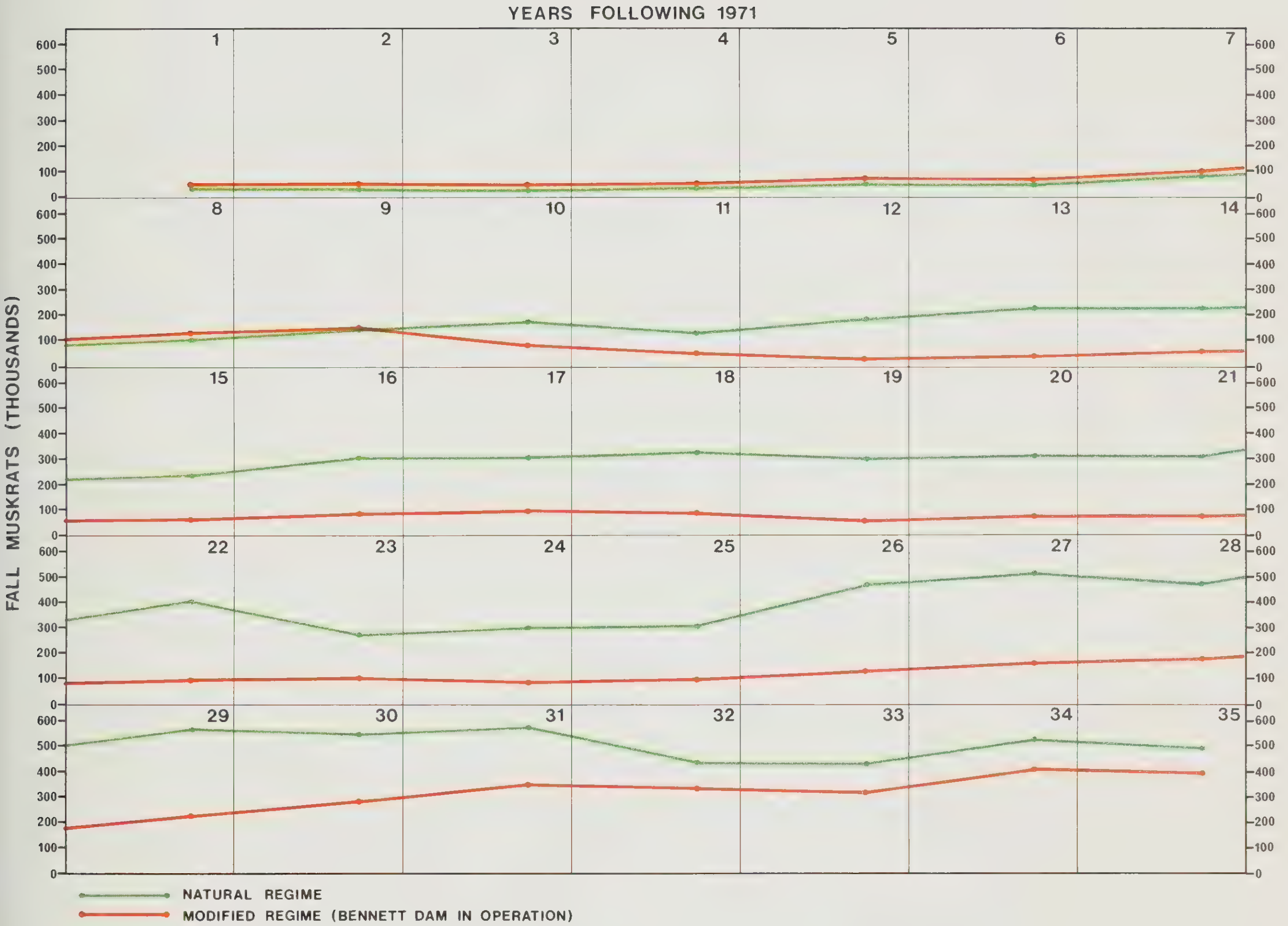


FIG. 14 Fall Muskrats Produced, Simulation Run E

Table 16. Over-winter carrying capacity for moose resulting from several simulaticn program runs comparing natural regime with modified regime.

Simulation Program Run	Mean Yearly Carrying Capacity Under Natural Regime	Increase Due to Modified Regime
RUN D - 35 years	3,800	16%
RUN E - 35 years	3,900	15%
RUN F - 35 years	3,600	15%
RUN G - 70 years	3,800	19%
RUN H - 70 years	4,000	18%

ASSESSMENT OF STRUCTURES TO RESTORE NATURAL REGIME

Another major aspect of the Project study was the assessment of alternatives available for restoring the Delta to 'natural' or pre-Dam conditions. Engineering studies of possible remedial structures were carried out concurrently with ecological studies in anticipation of it being concluded that sufficient undesirable environmental changes would likely occur without remedial action. The choices given most active consideration were (Figure 15):

1. Gated control structure on Slave River.
2. Gated control structure on Rochers River.
3. Rock constriction structure on Slave River.
4. Rock constriction on Rochers River.
5. Rock weir structure on Rochers River.
6. Ice dam on Rochers River.

Simulated Lake Athabasca levels were produced for each of the above alternatives (Volume 1, Appendix F) except for the ice dam. Those produced for the gated control structures resulted in regimes considerably higher than the natural regime, and they did not warrant further testing for suitability. However, because these structures would be capable of raising water levels higher than desired, it was concluded that with modifications to discharge capacity, either could be changed to duplicate almost exactly the natural regime, if enough attention were given to manipulaticn of gates to achieve this goal. Therefore there was no need to simulate effects of a properly managed gated structure, since the simulated results would be

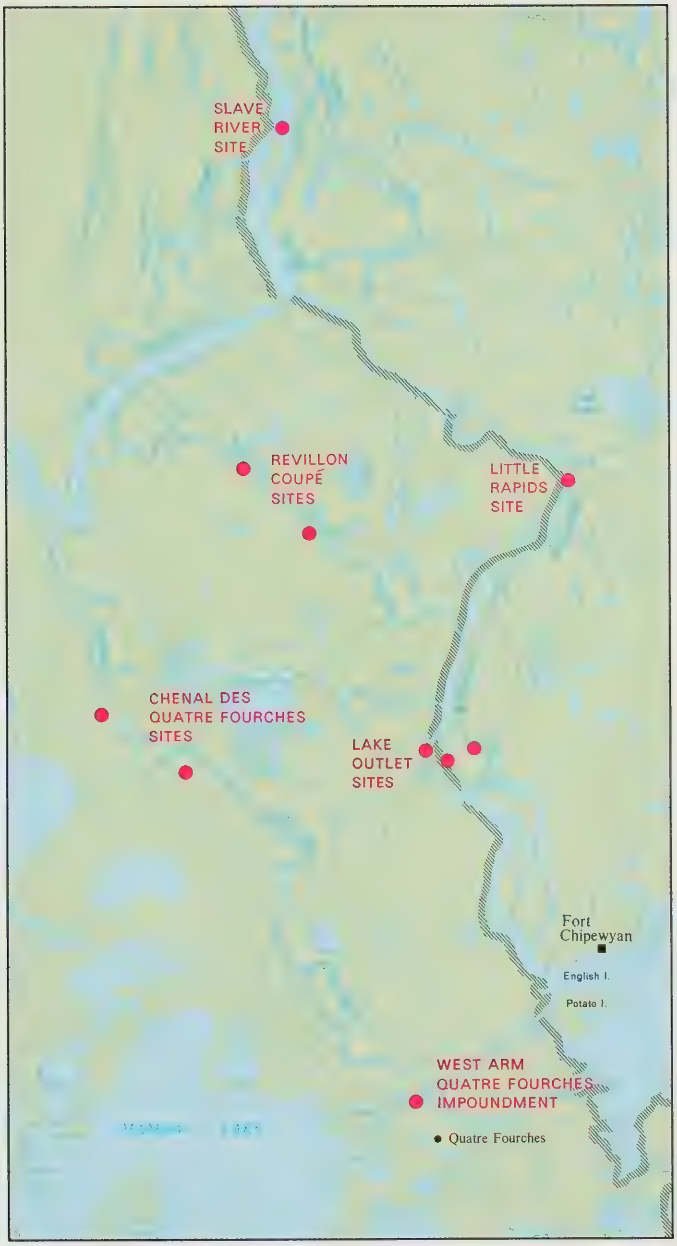


FIG. 15 Alternative Sites for Remedial Works

identical to those of the natural regime.

For the remaining alternatives, the Slave constriction, Rochers constriction, and Rochers weir, a number of wildlife simulation runs were assembled. The pool of simulated water levels for the 12-year period beginning in 1960 was obtained from the hydrology simulation model (Volume 1, Appendix F) and reduced to five ecological time periods according to the procedure described for simulating the natural regime. These are given in Tables 17,18, and 19. Then to make all runs comparable to previous runs of the natural and modified regimes, the identical sequences of years with their associated water levels were assembled for input to the wildlife model (Appendix 1). Comparative group runs D and E were used.

Simulated Lake levels for the Slave constriction, group run E, are given in Figure 16. The structure as designed would flood the Delta for a longer time during the growing season than would the natural regime and thus would retard plant succession more than under natural conditions. This is evidenced by a positive departure from natural in the predicted acreage of open water, and a negative departure in acres of shrubs and forests (Table 20). It would restore approximately one-half of the perched basin shore miles that are predicted to be lost under the modified regime. Waterfowl production would be satisfactorily restored, although muskrat habitat and populations would be only partly restored (Table 20). Some destruction of moose habitat would be anticipated, and bison habitat would be improved.

Table 17. Simulated water levels with Slave River constriction in operation, from which individual years were chosen to make program runs.

Year	Ecological Time Period				
	1	2	3	4	5
1960	684.9	686.7	688.7	688.3	687.3
1961	689.3	689.0	688.4	686.8	684.1
1962	687.2	689.3	690.6	689.9	686.7
1963	689.5	690.7	689.8	688.2	685.3
1964	686.9	688.2	688.4	689.1	687.1
1965	689.9	690.9	692.1	690.3	687.3
1966	689.3	690.2	689.7	689.1	686.2
1967	688.5	690.5	690.6	688.8	685.5
1968	687.3	688.1	689.0	687.4	685.8
1969	689.6	689.3	687.9	686.0	684.0
1970	685.6	685.4	685.3	684.3	683.8
1971	686.1	686.9	690.0	687.9	684.0

Table 18. Simulated water levels with Rochers River constriction in operation, from which individual years were chosen tc make program runs.

Year	Ecological Time Period				
	1	2	3	4	5
1960	684.3	686.0	687.7	689.3	688.2
1961	688.8	689.3	688.9	688.2	685.3
1962	687.3	689.2	690.1	690.5	687.6
1963	689.2	690.4	689.9	689.2	686.4
1964	687.1	688.2	688.1	689.0	687.7
1965	689.4	690.4	694.1	690.8	688.0
1966	688.9	689.9	689.9	690.2	687.4
1967	688.6	690.3	690.5	690.0	686.9
1968	687.4	688.1	689.1	688.4	686.9
1969	689.1	689.5	688.6	687.4	685.1
1970	686.1	686.7	687.7	686.9	685.5
1971	686.7	687.7	690.1	688.8	685.1

Table 19. Simulated water levels with Rochers River weir in operation, from which individual years were chosen to make program runs.

Year	Ecological Time Period				
	1	2	3	4	5
1960	684.3	686.0	687.5	688.9	687.7
1961	688.2	688.6	688.1	687.5	684.9
1962	687.0	688.7	689.4	689.7	686.7
1963	688.6	689.6	689.0	688.2	685.7
1964	686.5	687.5	687.3	688.3	687.0
1965	688.9	689.7	690.5	689.7	687.0
1966	688.2	689.2	689.0	689.0	686.5
1967	687.9	689.7	689.5	689.0	686.1
1968	686.8	687.4	688.3	687.6	686.3
1969	688.9	688.7	687.8	686.8	684.6
1970	685.7	686.5	687.6	686.8	685.2
1971	686.4	687.4	689.5	688.2	684.6

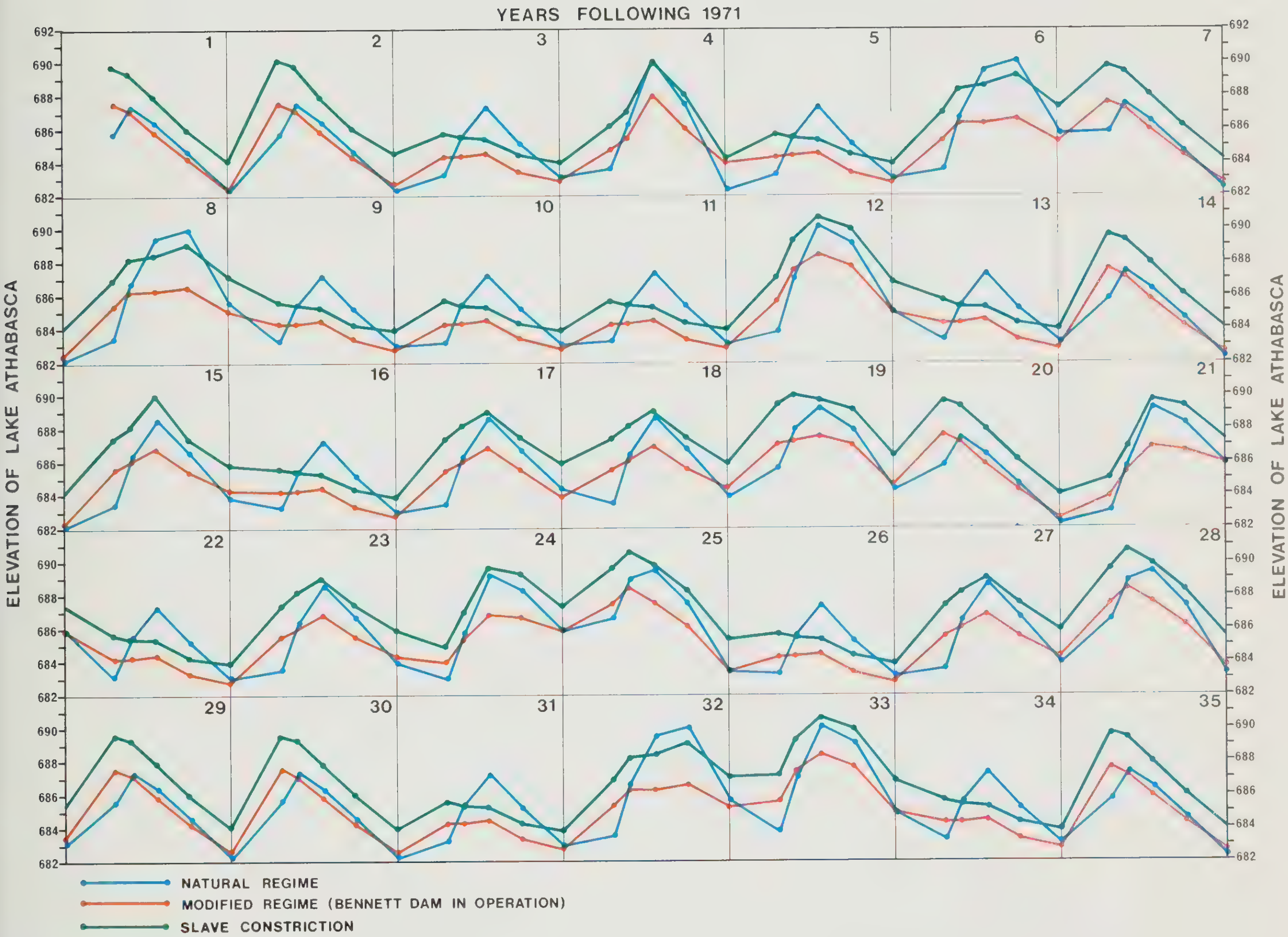


FIG. 16 Simulated Lake Levels Resulting from Slave Constriction, Run E

Table 20. Results of group run E, random selection of 35 years from 35-year pool of 1937-71.

	AVERAGE ANNUAL PRODUCTION	AVERAGE ANNUAL DEVIATION FROM NATURAL			
	Natural	Modified	Slave Constriction	Rochers Constriction	Rochers Weir
<u>Habitat Acres</u>					
Open Water	447,000	-13%	+22%	+29%	+12%
Productive Habitats*	364,000	- 9%	- 3%	- 7%	- 2%
Shrubs and Forests	601,000	+16%	-14%	-17%	- 7%
<u>Shoreline Miles</u>					
Perched Basins	5,700	-51%	-21%	-12%	-24%
<u>Animal Numbers</u>					
Dabblers	204,000	-28%	- 3%	- 1%	- 3%
Divers	99,000	-22%	+13%	- 2%	+11%
Ducks	303,000	-26%	+ 2%	- 1%	+ 2%
Muskrats (Spring)	81,000	-60%	-27%	-30%	- 5%
Muskrats (Fall)	265,000	-56%	-20%	-25%	+ 5%
Carrying Capacity Muskrats	159,000	-50%	-34%	- 2%	+ 4%
Carrying Capacity Moose	3,900	+15%	- 7%	-10%	- 5%
Carrying Capacity Bison	27,000	0%	+ 3%	- 2%	+ 1%

*Includes emergents, mud flat, immature fen, and meadows, all of which are early successional habitat types.

The Rochers constriction in operation would raise levels during the growing season somewhat above those of the natural regime (Figure 17). This would cause plant succession to progress more slowly than under natural conditions, and it would increase the acreage of Delta reverting to open water (Table 20). The improvement in amount of the productive habitats would be small, but the high peak levels would substantially increase the length of shoreline by refilling a high percentage of perched basins. Waterfowl production would be almost completely restored, while muskrat populations would be only partly restored. Some destruction of moose habitat would occur and the carrying capacity for bison would be only slightly changed.

Simulated Lake levels for the Rochers weir, group run E, are given in Figure 18. Of the three fixed-crest alternatives, the weir would come the closest to restoring the natural rate of plant succession on the Delta (Table 20). But midsummer peaks would not be as high as under natural conditions, and therefore complete restoration of natural shore miles would not be accomplished. Production of waterfowl would be essentially completely restored, because the ducks would be more successful on account of a smaller amplitude in flooding, even with fewer perched miles available. Muskrat habitat and populations would be completely restored (Table 20). A slight reduction in moose habitat would occur, but bison carrying capacity would change very little.

A unique method of raising water levels on Lake Athabasca was considered in detail by the Delta Project. It involved blocking

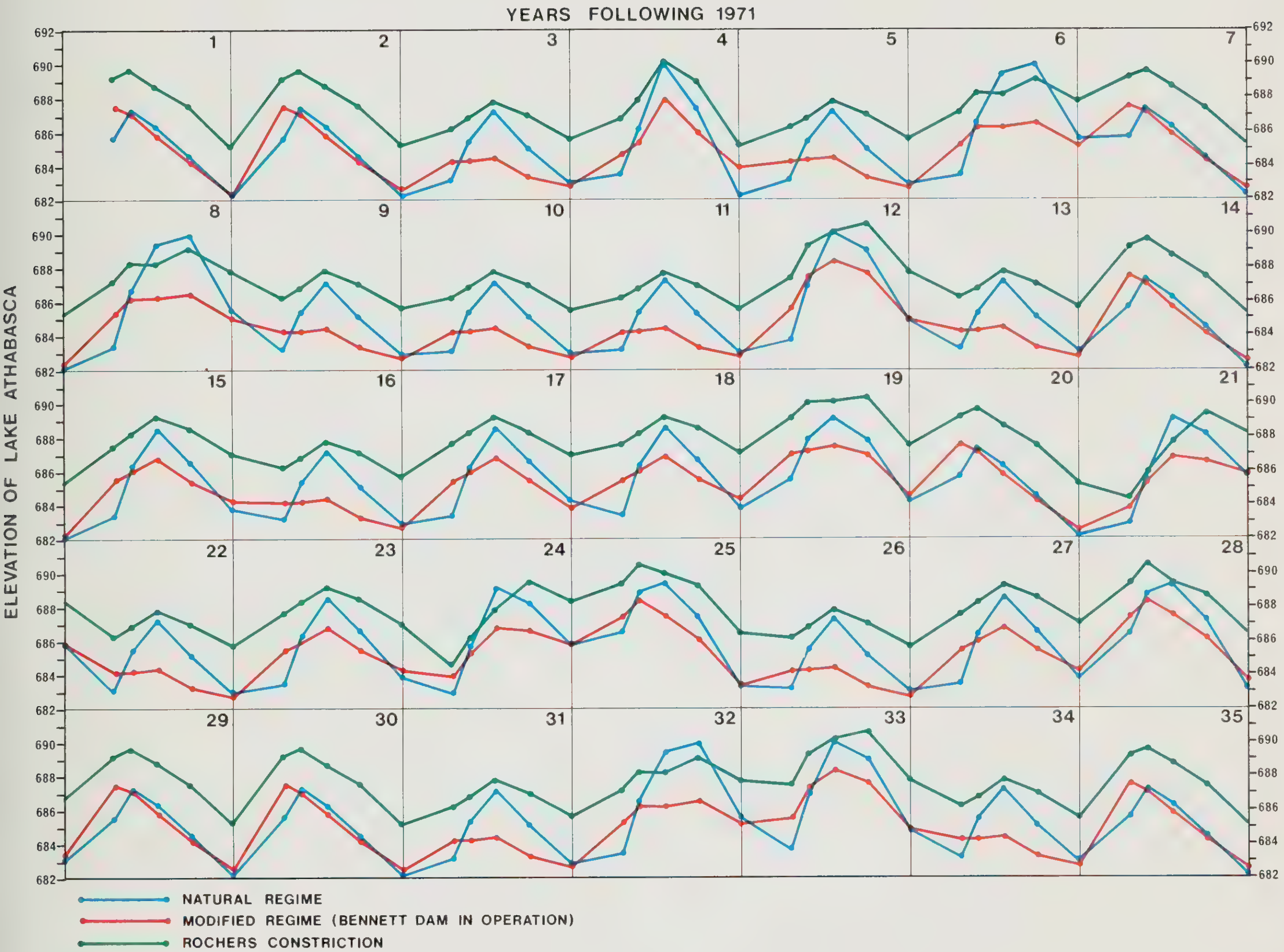


FIG. 17 Simulated Lake Levels Resulting from Rochers Constriction, Run E

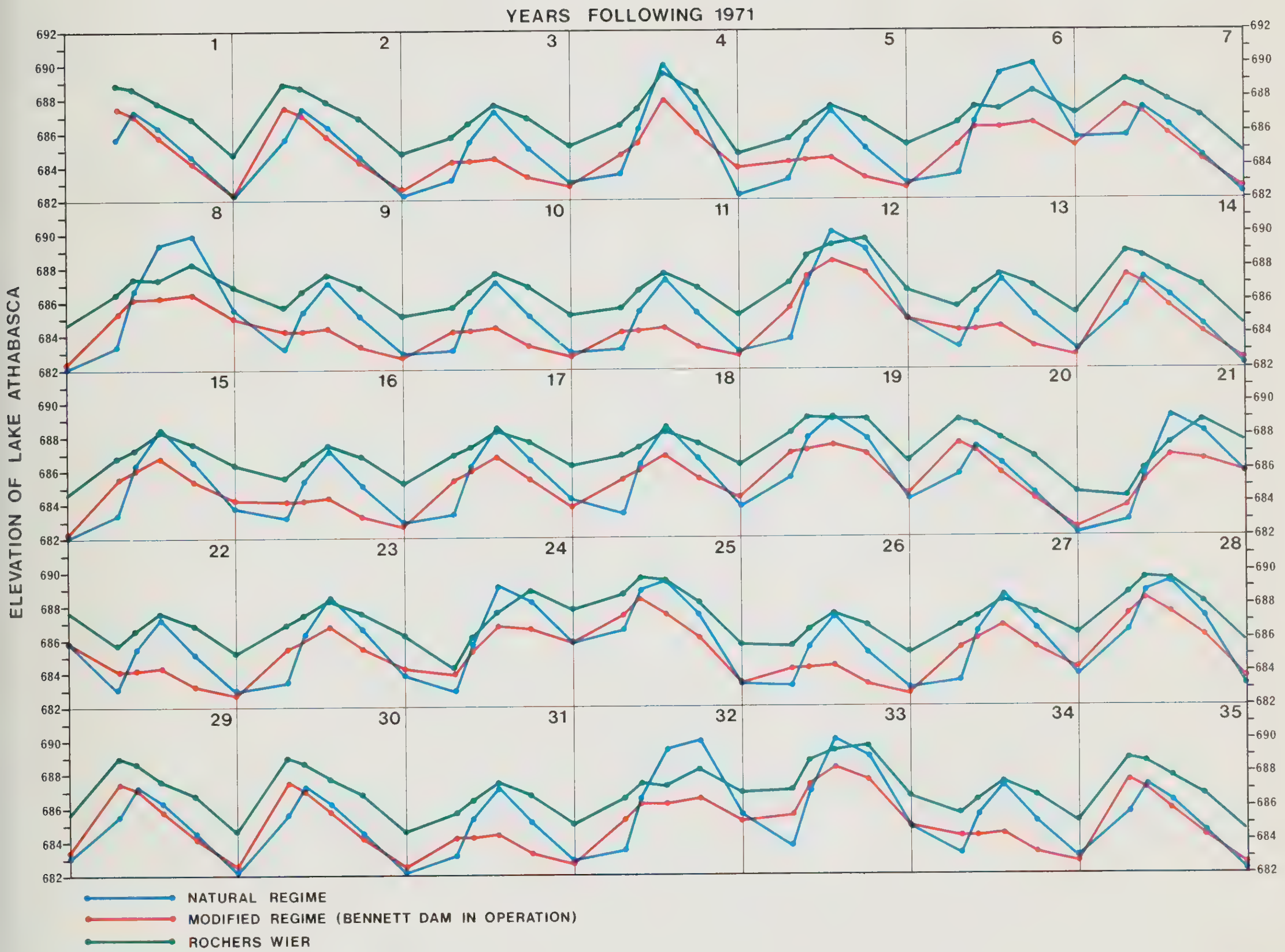


FIG. 18 Simulated Lake Levels Resulting from Rochers Weir, Run E

the Rochers River during winter with a solid dam of ice constructed by using hollow pilings filled with a refrigerant kept circulating by cold winter air (Volume 1, Appendix G). The dam would be kept in place until mid-July while water increased to flood levels and filled the Delta perched lakes, similar to the flooding which occurred during several years in the 1960's. The structure would then be destroyed and during the last half of summer the lake levels would recede.

The predicted hydrograph with the ice dam in place was quite similar to that of the natural regime, (Volume 1, Appendix G) except that water levels would begin rising on Lake Athabasca during late winter before breakup. The chief disadvantage of the scheme was that the dam would not restore the natural regime during years when it was not in place, and would have to be constructed periodically (every few years) in order to provide continual improvement over the modified regime.

The wildlife model was used to test various schedules of ice dam placement. Under natural conditions, summer flooding was unpredictable, but both beneficial and harmful when it did occur. Under the modified regime the severity and frequency of flooding is less, and refilling of the perched lakes is less frequent. Ice dam placement was simulated for intervals of 4, 5, 6, and 7 years by inserting the ice dam regime into the water level series of the modified regime for group run A at appropriate intervals (Appendix 1). The simulated effects on wildlife productivity are compared with those of the natural and modified regimes of the same group run A (Table 21).

Table 21. Average annual production with simulated ice dam placement, group run A.

	Natural Regime	Modified Regime	Modified Regime With ICE DAM Every 4 YEARS	5 YEARS	6 YEARS	7 YEARS
Habitat Acres						
Open Water	508,442	413,113	470,232	455,048	454,269	454,090
Emergents	239,992	154,684	252,275	243,743	239,924	221,382
Duck Staging Habitat (Fall)	26,774	57,018	60,733	57,871	49,249	52,316
Mud Flats	11,624	12,127	18,353	12,204	11,610	13,030
Immature Fen	4,842	31,847	28,954	35,275	28,300	24,602
Carex Meadow	37,162	48,974	53,049	67,246	78,857	94,963
Calamagrostis Meadow	55,269	86,975	52,454	55,247	55,366	57,419
Low Shrub	121,516	151,142	136,953	136,502	134,144	136,243
Tall Shrub	334,258	393,054	321,340	321,244	320,698	318,212
Deciduous	98,884	120,078	78,382	85,486	88,822	92,049
Shoreline Miles						
Perched Basins	5,875	2,946	7,425	7,009	6,688	6,340
Animal Numbers						
Dabblers	198,977	106,467	278,351	266,235	252,417	241,010
Divers	94,414	47,285	132,674	122,099	115,948	108,542
Ducks	293,390	153,750	411,027	388,333	368,365	349,551
Muskrats (Spring)	59,153	15,292	63,108	66,279	61,864	51,983
Muskrats (Fall)	193,072	52,844	203,370	218,421	207,720	176,978
Carrying Capacity Muskrats	107,148	50,773	123,629	125,244	124,288	116,659
Carrying Capacity Moose	3,762	4,366	3,537	3,550	3,551	3,554
Carrying Capacity Bison	25,912	24,990	28,544	28,873	30,109	30,902

It is evident that waterfowl production could be increased considerably over the natural regime if the Delta were flooded every four years (Table 21), even at the expense of high nest loss during the ice dam years. The length of perched basin shoreline averages highest for this sequence. Muskrat production would appear to benefit most from flooding every fifth year. Moose carrying capacity is greatest under the regulated regime, and bison carrying capacity is highest with the ice dam in effect every seven years (Table 21).

The high wildlife production under the ice dam regimes is due to the regularity in setting back plant succession to early stages (mud flats, immature fen, emergents), and the frequent refilling of perched lakes important to many of the Delta fauna. These regimes must be considered as managed or planned regimes, and they depart significantly from the natural regime in which timing of flooding is not as regular. If restoration to natural is the objective (and this is certainly to be given consideration within Wood Buffalo National Park) then the ice dam regime is probably not an appropriate choice. If sustained management of the Delta's wildlife resources becomes the objective, then the ice dam regimes given here deserve further consideration along with an analysis of the cost of their periodic reconstruction.

LIMITATIONS OF MODEL, IMPROVEMENTS, OTHER USES

One of the limitations of this model is the lack of a measurable standard by which to judge reliability of the results. The hydrologic model was "calibrated" by using a known series of hydrographs with which simulated hydrographs were compared (Appendix C, Volume 1). But historical population data on animals of the Delta were only fragmentary and long records of accurate census information would be required to "calibrate" using the hydrologic approach. The only method available in assessing the wildlife model was the careful evaluation of results to see if they were biologically and ecologically reasonable and withstood a subjective analysis. Long-term monitoring of the ecological processes of the Delta would be necessary to ultimately judge the precision of the wildlife simulation model.

It would have been helpful when conducting the comparative tests of regimes if the hydrologic and wildlife models were joined by several programming steps which would have summarized the five-day means into the ecological time periods and prepared appropriate runs. It would have also been useful to have the major fish species included in the model, since any water management decision on the Delta could have an important effect on fish populations there.

Time did not permit a thorough search for water level regimes to maximize production for the major species. Even the comparative examinations of impacts of structures were restricted to the 12

years of water level data of the 1960s. The model could be used to test a number of other regimes in order to further explore the complicated interrelationships of water levels, plant succession and wildlife productivity. For example, long or short cycles of dry or wet years could be simulated. Various marsh management practices, including periodic drawdowns of marshes, could be tested for short- and long-term effects. With minor program modification tc print results after each year of water level input, a 'manager' could, during one session at the computer terminal, decide on water levels a year at a time, and make his next year's selection of water levels on the basis of the 'current' productivity of or trends in the animal populations. The use of ccmputer graphics in presentation of results could be extremely useful in the analyses.

The model has another use. Wildlife population data used as input could be varied between successive runs to test the sensitivity of each parameter and determine how precise the census data should be. It may be that time and money could be saved on subsequent similar studies with this type of analysis.

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Mackay, Ron, Supervisor of Surveys & Enforcement, CWS. Technical

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Telfer, Edmund, Biclogist, CWS. Technical data in moose.

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Yaremko, E. K. 1973. Ice dam concept. Appendix G, Volume 1, Hydrologic Investigations. Peace-Athabasca Delta Project.

Appendix 1. Water levels used as input for comparative group runs.

Group Runs A & D--Natural Regime							
Year	Ecological Time Period					Trap	Year
	1	2	3	4	5	Code	Used
1971	684.5	686.0	687.0	686.0	684.0	0	----
1972	686.5	688.9	691.4	689.2	684.9	1	1965
1973	686.5	688.9	691.4	689.2	684.9	1	1965
1974	683.5	686.4	688.7	686.7	683.9	1	1968
1975	683.3	685.4	687.3	685.2	683.0	1	1970
1976	683.3	685.4	687.3	685.2	683.0	1	1970
1977	685.7	687.4	686.4	684.5	682.1	1	1969
1978	683.3	685.4	687.3	685.2	683.0	1	1970
1979	683.5	686.4	688.7	686.7	683.9	1	1968
1980	683.5	686.4	688.7	686.7	683.9	1	1968
1981	683.3	685.4	687.3	685.2	683.0	1	1970
1982	685.7	687.4	686.4	684.5	682.1	1	1969
1983	683.3	685.4	687.3	685.2	683.0	1	1970
1984	685.7	687.4	686.4	684.5	682.1	1	1969
1985	683.6	686.0	690.0	687.4	682.1	1	1971
1986	683.3	685.4	687.3	685.2	683.0	1	1970
1987	683.3	685.4	687.3	685.2	683.0	1	1970
1988	685.7	687.4	686.4	684.5	682.1	1	1969
1989	683.3	685.4	687.3	685.2	683.0	1	1970
1990	683.3	685.4	687.3	685.2	683.0	1	1970
1991	684.9	688.6	690.4	688.1	683.5	1	1967
1992	683.5	686.4	688.7	686.7	683.9	1	1968
1993	683.3	685.4	687.3	685.2	683.0	1	1970
1994	683.3	685.4	687.3	685.2	683.0	1	1970
1995	683.5	686.4	688.7	686.7	683.9	1	1968
1996	685.7	687.4	686.4	684.5	682.1	1	1969
1997	682.7	685.5	689.2	688.3	685.8	1	1960
1998	685.9	688.3	689.1	686.3	682.1	1	1961
1999	683.7	686.8	690.1	689.1	684.8	1	1962
2000	686.5	688.8	689.4	687.3	683.2	1	1963
2001	683.5	686.7	689.5	690.0	685.6	1	1964
2002	686.5	688.9	691.4	689.2	684.9	1	1965
2003	685.6	687.9	689.2	688.4	684.2	1	1966
2004	684.9	688.6	690.4	688.1	683.5	1	1967
2005	683.5	686.4	688.7	686.7	683.9	1	1968
2006	685.7	687.4	686.4	684.5	682.1	1	1969

(Continued on next page.)

Appendix 1. Continued.

Group Runs A & D--Modified Regime (Bennett Dam)							
Year	Ecological Time Period					Trap	Year
	1	2	3	4	5	Code	Used
1971	684.5	686.0	687.0	686.0	684.0	0	----
1972	687.7	688.6	689.3	687.9	685.2	1	1965
1973	687.7	688.6	689.3	687.9	685.2	1	1965
1974	685.4	686.0	686.8	685.5	684.2	1	1968
1975	684.1	684.1	684.4	683.3	682.7	1	1970
1976	684.1	684.1	684.4	683.3	682.7	1	1970
1977	687.6	687.2	685.9	684.2	682.5	1	1969
1978	684.1	684.1	684.4	683.3	682.7	1	1970
1979	685.4	686.0	686.8	685.5	684.2	1	1968
1980	685.4	686.0	686.8	685.5	684.2	1	1968
1981	684.1	684.1	684.4	683.3	682.7	1	1970
1982	687.6	687.2	685.9	684.2	682.5	1	1969
1983	684.1	684.1	684.4	683.3	682.7	1	1970
1984	687.6	687.2	685.9	684.2	682.5	1	1969
1985	684.6	685.4	687.9	686.0	683.9	1	1971
1986	684.1	684.1	684.4	683.3	682.7	1	1970
1987	684.1	684.1	684.4	683.3	682.7	1	1970
1988	687.6	687.2	685.9	684.2	682.5	1	1969
1989	684.1	684.1	684.4	683.3	682.7	1	1970
1990	684.1	684.1	684.4	683.3	682.7	1	1970
1991	686.6	688.5	688.1	686.8	683.9	1	1967
1992	685.4	686.0	686.8	685.5	684.2	1	1968
1993	684.1	684.1	684.4	683.3	682.7	1	1970
1994	684.1	684.1	684.4	683.3	682.7	1	1970
1995	685.4	686.0	686.8	685.5	684.2	1	1968
1996	687.6	687.2	685.9	684.2	682.5	1	1969
1997	683.9	685.4	686.9	686.6	685.7	1	1960
1998	687.3	687.0	686.4	685.0	682.6	1	1961
1999	685.5	687.4	688.3	687.7	684.8	1	1962
2000	687.4	688.4	687.5	686.1	683.5	1	1963
2001	685.2	686.3	686.2	686.7	685.2	1	1964
2002	687.7	688.6	689.3	687.9	685.2	1	1965
2003	687.0	688.0	687.5	687.0	684.5	1	1966
2004	686.6	688.5	688.1	686.8	683.9	1	1967
2005	685.4	686.0	686.8	685.5	684.2	1	1968
2006	687.6	687.2	685.9	684.2	682.5	1	1969

(Continued on next page.)

Appendix 1. Continued.

Group Runs A & D--Proposed Rochers Weir							
Year	Ecological Time Period					Trap	Year
	1	2	3	4	5	Code	Used
1971	684.5	686.0	687.0	686.0	684.0	0	----
1972	688.9	689.7	690.5	689.7	687.0	1	1965
1973	688.9	689.7	690.5	689.7	687.0	1	1965
1974	686.8	687.4	688.3	687.6	686.3	1	1968
1975	685.7	686.5	687.6	686.8	685.2	1	1970
1976	685.7	686.5	687.6	686.8	685.2	1	1970
1977	688.9	688.7	687.8	686.8	684.6	1	1969
1978	685.7	686.5	687.6	686.8	685.2	1	1970
1979	686.8	687.4	688.3	687.6	686.3	1	1968
1980	686.8	687.4	688.3	687.6	686.3	1	1968
1981	685.7	686.5	687.6	686.8	685.2	1	1970
1982	688.9	688.7	687.8	686.8	684.6	1	1969
1983	685.7	686.5	687.6	686.8	685.2	1	1970
1984	688.9	688.7	687.8	686.8	684.6	1	1969
1985	686.4	687.4	689.5	688.2	684.6	1	1971
1986	685.7	686.5	687.6	686.8	685.2	1	1970
1987	685.7	686.5	687.6	686.8	685.2	1	1970
1988	688.9	688.7	687.8	686.8	684.6	1	1969
1989	685.7	686.5	687.6	686.8	685.2	1	1970
1990	685.7	686.5	687.6	686.8	685.2	1	1970
1991	687.9	689.7	689.5	689.0	686.1	1	1967
1992	686.8	687.4	688.3	687.6	686.3	1	1968
1993	685.7	686.5	687.6	686.8	685.2	1	1970
1994	685.7	686.5	687.6	686.8	685.2	1	1970
1995	686.8	687.4	688.3	687.6	686.3	1	1968
1996	688.9	688.7	687.8	686.8	684.6	1	1969
1997	684.3	686.0	687.5	688.9	687.7	1	1960
1998	688.2	688.6	688.1	687.5	684.9	1	1961
1999	687.0	688.7	689.4	689.7	686.7	1	1962
2000	688.6	689.6	689.0	688.2	685.7	1	1963
2001	686.5	687.5	687.3	688.3	687.0	1	1964
2002	688.9	689.7	690.5	689.7	687.0	1	1965
2003	688.2	689.2	689.0	689.0	686.5	1	1966
2004	687.9	689.7	689.5	689.0	686.1	1	1967
2005	686.8	687.4	688.3	687.6	686.3	1	1968
2006	688.9	688.7	687.8	686.8	684.6	1	1969

(Continued on next page.)

Appendix 1. Continued.

Group Runs A & D--Proposed Rochers River Constriction							
Year	Ecological Time Period					Trap	Year
	1	2	3	4	5	Code	Used
1971	684.5	686.0	687.0	686.0	684.0	0	----
1972	689.4	690.4	694.1	690.8	688.0	1	1965
1973	689.4	690.4	694.1	690.8	688.0	1	1965
1974	687.4	688.1	689.1	688.4	686.9	1	1968
1975	686.1	686.7	687.7	686.9	685.5	1	1970
1976	686.1	686.7	687.7	686.9	685.5	1	1970
1977	689.1	689.5	688.6	687.4	685.1	1	1969
1978	686.1	686.7	687.7	686.9	685.5	1	1970
1979	687.4	688.1	689.1	688.4	686.9	1	1968
1980	687.4	688.1	689.1	688.4	686.9	1	1968
1981	686.1	686.7	687.7	686.9	685.5	1	1970
1982	689.1	689.5	688.6	687.4	685.1	1	1969
1983	686.1	686.7	687.7	686.9	685.5	1	1970
1984	689.1	689.5	688.6	687.4	685.1	1	1969
1985	686.7	687.7	690.1	688.8	685.1	1	1971
1986	686.1	686.7	687.7	686.9	685.5	1	1970
1987	686.1	686.7	687.7	686.9	685.5	1	1970
1988	689.1	689.5	688.6	687.4	685.1	1	1969
1989	686.1	686.7	687.7	686.9	685.5	1	1970
1990	686.1	686.7	687.7	686.9	685.5	1	1970
1991	688.6	690.3	690.5	690.0	686.9	1	1967
1992	687.4	688.1	689.1	688.4	686.9	1	1968
1993	686.1	686.7	687.7	686.9	685.5	1	1970
1994	686.1	686.7	687.7	686.9	685.5	1	1970
1995	687.4	688.1	689.1	688.4	686.9	1	1968
1996	689.1	689.5	688.6	687.4	685.1	1	1969
1997	684.3	686.0	687.7	689.3	688.2	1	1960
1998	688.8	689.3	688.9	688.2	685.3	1	1961
1999	687.3	689.2	690.1	690.5	687.6	1	1962
2000	689.2	690.4	689.9	689.2	686.4	1	1963
2001	687.1	688.2	688.1	689.0	687.7	1	1964
2002	689.4	690.4	694.1	690.8	688.0	1	1965
2003	688.9	689.9	689.9	690.2	687.4	1	1966
2004	688.6	690.3	690.5	690.0	686.9	1	1967
2005	687.4	688.1	689.1	688.4	686.9	1	1968
2006	689.1	689.5	688.6	687.4	685.1	1	1969

(Continued on next page.)

Appendix 1. Continued.

Group Runs A & D--Proposed Slave River Constriction

Year	Ecological Time Period 1	2	3	4	5	Trap Code	Year Used
1971	684.5	686.0	687.0	686.0	684.0	0	----
1972	689.9	690.9	692.1	690.3	687.3	1	1965
1973	689.9	690.9	692.1	690.3	687.3	1	1965
1974	687.3	688.1	689.0	687.4	685.8	1	1968
1975	685.6	685.4	685.3	684.3	683.8	1	1970
1976	685.6	685.4	685.3	684.3	683.8	1	1970
1977	689.6	689.3	687.9	686.0	684.0	1	1969
1978	685.6	685.4	685.3	684.3	683.8	1	1970
1979	687.3	688.1	689.0	687.4	685.8	1	1968
1980	687.3	688.1	689.0	687.4	685.8	1	1968
1981	685.6	685.4	685.3	684.3	683.8	1	1970
1982	689.6	689.3	687.9	686.0	684.0	1	1969
1983	685.6	685.4	685.3	684.3	683.8	1	1970
1984	689.6	689.3	687.9	686.0	684.0	1	1969
1985	686.1	686.9	690.0	687.9	684.0	1	1971
1986	685.6	685.4	685.3	684.3	683.8	1	1970
1987	685.6	685.4	685.3	684.3	683.8	1	1970
1988	689.6	689.3	687.9	686.0	684.0	1	1969
1989	685.6	685.4	685.3	684.3	683.8	1	1970
1990	685.6	685.4	685.3	684.3	683.8	1	1970
1991	688.5	690.5	690.6	688.8	685.5	1	1967
1992	687.3	688.1	689.0	687.4	685.8	1	1968
1993	685.6	685.4	685.3	684.3	683.8	1	1970
1994	685.6	685.4	685.3	684.3	683.8	1	1970
1995	687.3	688.1	689.0	687.4	685.8	1	1968
1996	689.6	689.3	687.9	686.0	684.0	1	1969
1997	684.9	686.7	688.7	688.3	687.3	1	1960
1998	689.3	689.0	688.4	686.8	684.1	1	1961
1999	687.2	689.3	690.6	689.9	686.7	1	1962
2000	689.5	690.7	689.8	688.2	685.3	1	1963
2001	686.9	688.2	688.4	689.1	687.1	1	1964
2002	689.9	690.9	692.1	690.3	687.3	1	1965
2003	689.3	690.2	689.7	689.1	686.2	1	1966
2004	688.5	690.5	690.6	688.8	685.5	1	1967
2005	687.3	688.1	689.0	687.4	685.8	1	1968
2006	689.6	689.3	687.9	686.0	684.0	1	1969

(Continued on next page.)

Appendix 1. Continued.

Group Run B -- Natural Regime							
Year	Ecological Time Period					Trap	Year
	1	2	3	4	5	Code	Used
1971	684.5	686.0	687.0	686.0	684.0	0	----
1972	682.7	685.5	689.2	688.3	685.8	1	1960
1973	685.9	688.3	689.1	686.3	682.1	1	1961
1974	683.7	686.8	690.1	689.1	684.8	1	1962
1975	686.5	688.8	689.4	687.3	683.2	1	1963
1976	683.5	686.7	689.5	690.0	685.6	1	1964
1977	686.5	688.9	691.4	689.2	684.9	1	1965
1978	685.6	687.9	689.2	688.4	684.2	1	1966
1979	684.9	688.6	690.4	688.1	683.5	1	1967
1980	683.5	686.4	688.7	686.7	683.9	1	1968
1981	685.7	687.4	686.4	684.5	682.1	1	1969
1982	683.3	685.4	687.3	685.2	683.0	1	1970
1983	683.6	686.0	690.0	687.4	682.1	1	1971
1984	682.7	685.5	689.2	688.3	685.8	1	1960
1985	685.9	688.3	689.1	686.3	682.1	1	1961
1986	683.7	686.8	690.1	689.1	684.8	1	1962
1987	686.5	688.8	689.4	687.3	683.2	1	1963
1988	683.5	686.7	689.5	690.0	685.6	1	1964
1989	686.5	688.9	691.4	689.2	684.9	1	1965
1990	685.6	687.9	689.2	688.4	684.2	1	1966
1991	684.9	688.6	690.4	688.1	683.5	1	1967
1992	683.5	686.4	688.7	686.7	683.9	1	1968
1993	685.7	687.4	686.4	684.5	682.1	1	1969
1994	683.3	685.4	687.3	685.2	683.0	1	1970
1995	683.6	686.0	690.0	687.4	682.1	1	1971
1996	682.7	685.5	689.2	688.3	685.8	1	1960
1997	685.9	688.3	689.1	686.3	682.1	1	1961
1998	683.7	686.8	690.1	689.1	684.8	1	1962
1999	686.5	688.8	689.4	687.3	683.2	1	1963
2000	683.5	686.7	689.5	690.0	685.6	1	1964
2001	686.5	688.9	691.4	689.2	684.9	1	1965
2002	685.6	687.9	689.2	688.4	684.2	1	1966
2003	684.9	688.6	690.4	688.1	683.5	1	1967
2004	683.5	686.4	688.7	686.7	683.9	1	1968
2005	685.7	687.4	686.4	684.5	682.1	1	1969
2006	683.3	685.4	687.3	685.2	683.0	1	1970

(Continued on next page.)

Appendix 1. Continued.

Group Run B -- Modified Regime (Bennett Dam)							
Year	Ecological Time Period					Trap	Year
	1	2	3	4	5	Code	Used
1971	684.5	686.0	687.0	686.0	684.0	0	----
1972	683.9	685.4	686.9	686.6	685.7	1	1960
1973	687.3	687.0	686.4	685.0	682.6	1	1961
1974	685.5	687.4	688.3	687.7	684.8	1	1962
1975	687.4	688.4	687.5	686.1	683.5	1	1963
1976	685.2	686.3	686.2	686.7	685.2	1	1964
1977	687.7	688.6	689.3	687.9	685.2	1	1965
1978	687.0	688.0	687.5	687.0	684.5	1	1966
1979	686.6	688.5	688.1	686.8	683.9	1	1967
1980	685.4	686.0	686.8	685.5	684.2	1	1968
1981	687.6	687.2	685.9	684.2	682.5	1	1969
1982	684.1	684.1	684.4	683.3	682.7	1	1970
1983	684.6	685.4	687.9	686.0	683.9	1	1971
1984	683.9	685.4	686.9	686.6	685.7	1	1960
1985	687.3	687.0	686.4	685.0	682.6	1	1961
1986	685.5	687.4	688.3	687.7	684.8	1	1962
1987	687.4	688.4	687.5	686.1	683.5	1	1963
1988	685.2	686.3	686.2	686.7	685.2	1	1964
1989	687.7	688.6	689.3	687.9	685.2	1	1965
1990	687.0	688.0	687.5	687.0	684.5	1	1966
1991	686.6	688.5	688.1	686.8	683.9	1	1967
1992	685.4	686.0	686.8	685.5	684.2	1	1968
1993	687.6	687.2	685.9	684.2	682.5	1	1969
1994	684.1	684.1	684.4	683.3	682.7	1	1970
1995	684.6	685.4	687.9	686.0	683.9	1	1971
1996	683.9	685.4	686.9	686.6	685.7	1	1960
1997	687.3	687.0	686.4	685.0	682.6	1	1961
1998	685.5	687.4	688.3	687.7	684.8	1	1962
1999	687.4	688.4	687.5	686.1	683.5	1	1963
2000	685.2	686.3	686.2	686.7	685.2	1	1964
2001	687.7	688.6	689.3	687.9	685.2	1	1965
2002	687.0	688.0	687.5	687.0	684.5	1	1966
2003	686.6	688.5	688.1	686.8	683.9	1	1967
2004	685.4	686.0	686.8	685.5	684.2	1	1968
2005	687.6	687.2	685.9	684.2	682.5	1	1969
2006	684.1	684.1	684.4	683.3	682.7	1	1970

(Continued on next page.)

Appendix 1. Continued.

Group Run B -- Proposed Rochers Weir

Year	Ecological Time Period					Trap	Year
	1	2	3	4	5	Code	Used
1971	684.5	686.0	687.0	686.0	684.0	0	----
1972	684.3	686.0	687.5	688.9	687.7	1	1960
1973	688.2	688.6	688.1	687.5	684.9	1	1961
1974	687.0	688.7	689.4	689.7	686.7	1	1962
1975	688.6	689.6	689.0	688.2	685.7	1	1963
1976	686.5	687.5	687.3	688.3	687.0	1	1964
1977	688.9	689.7	690.5	689.7	687.0	1	1965
1978	688.2	689.2	689.0	689.0	686.5	1	1966
1979	687.9	689.7	689.5	689.0	686.1	1	1967
1980	686.8	687.4	688.3	687.6	686.3	1	1968
1981	688.9	688.7	687.8	686.8	684.6	1	1969
1982	685.7	686.5	687.6	686.8	685.2	1	1970
1983	686.4	687.4	689.5	688.2	684.6	1	1971
1984	684.3	686.0	687.5	688.9	687.7	1	1960
1985	688.2	688.6	688.1	687.5	684.9	1	1961
1986	687.0	688.7	689.4	689.7	686.7	1	1962
1987	688.6	689.6	689.0	688.2	685.7	1	1963
1988	686.5	687.5	687.3	688.3	687.0	1	1964
1989	688.9	689.7	690.5	689.7	687.0	1	1965
1990	688.2	689.2	689.0	689.0	686.5	1	1966
1991	687.9	689.7	689.5	689.0	686.1	1	1967
1992	686.8	687.4	688.3	687.6	686.3	1	1968
1993	688.9	688.7	687.8	686.8	684.6	1	1969
1994	685.7	686.5	687.6	686.8	685.2	1	1970
1995	686.4	687.4	689.5	688.2	684.6	1	1971
1996	684.3	686.0	687.5	688.9	687.7	1	1960
1997	688.2	688.6	688.1	687.5	684.9	1	1961
1998	687.0	688.7	689.4	689.7	686.7	1	1962
1999	688.6	689.6	689.0	688.2	685.7	1	1963
2000	686.5	687.5	687.3	688.3	687.0	1	1964
2001	688.9	689.7	690.5	689.7	687.0	1	1965
2002	688.2	689.2	689.0	689.0	686.5	1	1966
2003	687.9	689.7	689.5	689.0	686.1	1	1967
2004	686.8	687.4	688.3	687.6	686.3	1	1968
2005	688.9	688.7	687.8	686.8	684.6	1	1969
2006	685.7	686.5	687.6	686.8	685.2	1	1970

(Continued on next page.)

Appendix 1. Continued.

Group Run E -- Proposed Rochers River Constriction							
Year	Ecological Time Period					Trap	Year
	1	1	3	4	5	Code	Used
1971	684.5	686.0	687.0	686.0	684.0	0	----
1972	684.3	686.0	687.7	689.3	688.2	1	1960
1973	688.8	689.3	688.9	688.2	685.3	1	1961
1974	687.3	689.2	690.1	690.5	687.6	1	1962
1975	689.2	690.4	689.9	689.2	686.4	1	1963
1976	687.1	688.2	688.1	689.0	687.7	1	1964
1977	689.4	690.4	694.1	690.8	688.0	1	1965
1978	688.9	689.9	689.9	690.2	687.4	1	1966
1979	688.6	690.3	690.5	690.0	686.9	1	1967
1980	687.4	688.1	689.1	688.4	686.9	1	1968
1981	689.1	689.5	688.6	687.4	685.1	1	1969
1982	686.1	686.7	687.7	686.9	685.5	1	1970
1983	686.7	687.7	690.1	688.8	685.1	1	1971
1984	684.3	686.0	687.7	689.3	688.2	1	1960
1985	688.8	689.3	688.9	688.2	685.3	1	1961
1986	687.3	689.2	690.1	690.5	687.6	1	1962
1987	689.2	690.4	689.9	689.2	686.4	1	1963
1988	687.1	688.2	688.1	689.0	687.7	1	1964
1989	689.4	690.4	694.1	690.8	688.0	1	1965
1990	688.9	689.9	689.9	690.2	687.4	1	1966
1991	688.6	690.3	690.5	690.0	686.9	1	1967
1992	687.4	688.1	689.1	688.4	686.9	1	1968
1993	689.1	689.5	688.6	687.4	685.1	1	1969
1994	686.1	686.7	687.7	686.9	685.5	1	1970
1995	686.7	687.7	690.1	688.8	685.1	1	1971
1996	684.3	686.0	687.7	689.3	688.2	1	1960
1997	688.8	689.3	688.9	688.2	685.3	1	1961
1998	687.3	689.2	690.1	690.5	687.6	1	1962
1999	689.2	690.4	689.9	689.2	686.4	1	1963
2000	687.1	688.2	688.1	689.0	687.7	1	1964
2001	689.4	690.4	694.1	690.8	688.0	1	1965
2002	688.9	689.9	689.9	690.2	687.4	1	1966
2003	688.6	690.3	690.5	690.0	686.9	1	1967
2004	687.4	688.1	689.1	688.4	686.9	1	1968
2005	689.1	689.5	688.6	687.4	685.1	1	1969
2006	686.1	686.7	687.7	686.9	685.5	1	1970

(Continued on next page.)

Appendix 1. Continued.

Group Run B -- Proposed Slave River Constriction

Year	Ecological Time Period					Trap	Year
	1	2	3	4	5	Code	Used
1971	684.5	686.0	687.0	686.0	684.0	0	----
1972	684.9	686.7	688.7	688.3	687.3	1	1960
1973	689.3	689.0	688.4	686.8	684.1	1	1961
1974	687.2	689.3	690.6	689.9	686.7	1	1962
1975	689.5	690.7	689.8	688.2	685.3	1	1963
1976	686.9	688.2	688.4	689.1	687.1	1	1964
1977	689.9	690.9	692.1	690.3	687.3	1	1965
1978	689.3	690.2	689.7	689.1	686.2	1	1966
1979	688.5	690.5	690.6	688.8	685.5	1	1967
1980	687.3	688.1	689.0	687.4	685.8	1	1968
1981	689.6	689.3	687.9	686.0	684.0	1	1969
1982	685.6	685.4	685.3	684.3	683.8	1	1970
1983	686.1	686.9	690.0	687.9	684.0	1	1971
1984	684.9	686.7	688.7	688.3	687.3	1	1960
1985	689.3	689.0	688.4	686.8	684.1	1	1961
1986	687.2	689.3	690.6	689.9	686.7	1	1962
1987	689.5	690.7	689.8	688.2	685.3	1	1963
1988	686.9	688.2	688.4	689.1	687.1	1	1964
1989	689.9	690.9	692.1	690.3	687.3	1	1965
1990	689.3	690.2	689.7	689.1	686.2	1	1966
1991	688.5	690.5	690.6	688.8	685.5	1	1967
1992	687.3	688.1	689.0	687.4	685.8	1	1968
1993	689.6	689.3	687.9	686.0	684.0	1	1969
1994	685.6	685.4	685.3	684.3	683.8	1	1970
1995	686.1	686.9	690.0	687.9	684.0	1	1971
1996	684.9	686.7	688.7	688.3	687.3	1	1960
1997	689.3	689.0	688.4	686.8	684.1	1	1961
1998	687.2	689.3	690.6	689.9	686.7	1	1962
1999	689.5	690.7	689.8	688.2	685.3	1	1963
2000	686.9	688.2	688.4	689.1	687.1	1	1964
2001	689.9	690.9	692.1	690.3	687.3	1	1965
2002	689.3	690.2	689.7	689.1	686.2	1	1966
2003	688.5	690.5	690.6	688.8	685.5	1	1967
2004	687.3	688.1	689.0	687.4	685.8	1	1968
2005	689.6	689.3	687.9	686.0	684.0	1	1969
2006	685.6	685.4	685.3	684.3	683.8	1	1970

(Continued on next page.)

Appendix 1. Continued.

Group Run C--Natural Regime							
Year	Ecological Time Period					Trap	Year
	1	2	3	4	5	Code	Used
1971	684.5	686.0	687.0	686.0	684.0	0	----
1972	683.6	686.0	690.0	687.4	682.1	1	1971
1973	683.3	685.4	687.3	685.2	683.0	1	1970
1974	683.3	685.4	687.3	685.2	683.0	1	1970
1975	685.7	687.4	686.4	684.5	682.1	1	1969
1976	683.3	685.4	687.3	685.2	683.0	1	1970
1977	683.3	685.4	687.3	685.2	683.0	1	1970
1978	684.9	688.6	690.4	688.1	683.5	1	1967
1979	683.5	686.4	688.7	686.7	683.9	1	1968
1980	683.3	685.4	687.3	685.2	683.0	1	1970
1981	683.3	685.4	687.3	685.2	683.0	1	1970
1982	683.5	686.4	688.7	686.7	683.9	1	1968
1983	685.7	687.4	686.4	684.5	682.1	1	1969
1984	683.6	686.0	690.0	687.4	682.1	1	1971
1985	683.3	685.4	687.3	685.2	683.0	1	1970
1986	683.3	685.4	687.3	685.2	683.0	1	1970
1987	685.7	687.4	686.4	684.5	682.1	1	1969
1988	683.3	685.4	687.3	685.2	683.0	1	1970
1989	683.3	685.4	687.3	685.2	683.0	1	1970
1990	684.9	688.6	690.4	688.1	683.5	1	1967
1991	683.5	686.4	688.7	686.7	683.9	1	1968
1992	683.3	685.4	687.3	685.2	683.0	1	1970
1993	683.3	685.4	687.3	685.2	683.0	1	1970
1994	683.5	686.4	688.7	686.7	683.9	1	1968
1995	685.7	687.4	686.4	684.5	682.1	1	1969
1996	683.6	686.0	690.0	687.4	682.1	1	1971
1997	683.3	685.4	687.3	685.2	683.0	1	1970
1998	683.3	685.4	687.3	685.2	683.0	1	1970
1999	685.7	687.4	686.4	684.5	682.1	1	1969
2000	683.3	685.4	687.3	685.2	683.0	1	1970
2001	683.3	685.4	687.3	685.2	683.0	1	1970
2002	684.9	688.6	690.4	688.1	683.5	1	1967
2003	683.5	686.4	688.7	686.7	683.9	1	1968
2004	683.3	685.4	687.3	685.2	683.0	1	1970
2005	683.3	685.4	687.3	685.2	683.0	1	1970
2006	683.5	686.4	688.7	686.7	683.9	1	1968

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Appendix 1. Continued.

Group Run C--Modified Regime (Bennett Dam)							
Year	Ecological Time Period					Trap	Year
	1	2	3	4	5	Code	Used
1971	684.5	686.0	687.0	686.0	684.0	0	----
1972	684.6	685.4	687.9	686.0	683.9	1	1971
1973	684.1	684.1	684.4	683.3	682.7	1	1970
1974	684.1	684.1	684.4	683.3	682.7	1	1970
1975	687.6	687.2	685.9	684.2	682.5	1	1969
1976	684.1	684.1	684.4	683.3	682.7	1	1970
1977	684.1	684.1	684.4	683.3	682.7	1	1970
1978	686.6	688.5	688.1	686.8	683.9	1	1967
1979	685.4	686.0	686.8	685.5	684.2	1	1968
1980	684.1	684.1	684.4	683.3	682.7	1	1970
1981	684.1	684.1	684.4	683.3	682.7	1	1970
1982	685.4	686.0	686.8	685.5	684.2	1	1968
1983	687.6	687.2	685.9	684.2	682.5	1	1969
1984	684.6	685.4	687.9	686.0	683.9	1	1971
1985	684.1	684.1	684.4	683.3	682.7	1	1970
1986	684.1	684.1	684.4	683.3	682.7	1	1970
1987	687.6	687.2	685.9	684.2	682.5	1	1969
1988	684.1	684.1	684.4	683.3	682.7	1	1970
1989	684.1	684.1	684.4	683.3	682.7	1	1970
1990	686.6	688.5	688.1	686.8	683.9	1	1967
1991	685.4	686.0	686.8	685.5	684.2	1	1968
1992	684.1	684.1	684.4	683.3	682.7	1	1970
1993	684.1	684.1	684.4	683.3	682.7	1	1970
1994	685.4	686.0	686.8	685.5	684.2	1	1968
1995	687.6	687.2	685.9	684.2	682.5	1	1969
1996	684.6	685.4	687.9	686.0	683.9	1	1971
1997	684.1	684.1	684.4	683.3	682.7	1	1970
1998	684.1	684.1	684.4	683.3	682.7	1	1970
1999	687.6	687.2	685.9	684.2	682.5	1	1969
2000	684.1	684.1	684.4	683.3	682.7	1	1970
2001	684.1	684.1	684.4	683.3	682.7	1	1970
2002	686.6	688.5	688.1	686.8	683.9	1	1967
2003	685.4	686.0	686.8	685.5	684.2	1	1968
2004	684.1	684.1	684.4	683.3	682.7	1	1970
2005	684.1	684.1	684.4	683.3	682.7	1	1970
2006	685.4	686.0	686.8	685.5	684.2	1	1968

(Continued on next page.)

Appendix 1. Continued.

Group Run C--Proposed Rochers Weir							
Year	Ecological Time Period					Trap	Year
	1	2	3	4	5	Code	Used
1971	684.5	686.0	687.0	686.0	684.0	0	----
1972	686.4	687.4	689.5	688.2	684.6	1	1971
1973	685.7	686.5	687.6	686.8	685.2	1	1970
1974	685.7	686.5	687.6	686.8	685.2	1	1970
1975	688.9	688.7	687.8	686.8	684.6	1	1969
1976	685.7	686.5	687.6	686.8	685.2	1	1970
1977	685.7	686.5	687.6	686.8	685.2	1	1970
1978	687.9	689.7	689.5	689.0	686.1	1	1967
1979	686.8	687.4	688.3	687.6	686.3	1	1968
1980	685.7	686.5	687.6	686.8	685.2	1	1970
1981	685.7	686.5	687.6	686.8	685.2	1	1970
1982	686.8	687.4	688.3	687.6	686.3	1	1968
1983	688.9	688.7	687.8	686.8	684.6	1	1969
1984	686.4	687.4	689.5	688.2	684.6	1	1971
1985	685.7	686.5	687.6	686.8	685.2	1	1970
1986	685.7	686.5	687.6	686.8	685.2	1	1970
1987	688.9	688.7	687.8	686.8	684.6	1	1969
1988	685.7	686.5	687.6	686.8	685.2	1	1970
1989	685.7	686.5	687.6	686.8	685.2	1	1970
1990	687.9	689.7	689.5	689.0	686.1	1	1967
1991	686.8	687.4	688.3	687.6	686.3	1	1968
1992	685.7	686.5	687.6	686.8	685.2	1	1970
1993	685.7	686.5	687.6	686.8	685.2	1	1970
1994	686.8	687.4	688.3	687.6	686.3	1	1968
1995	688.9	688.7	687.8	686.8	684.6	1	1969
1996	686.4	687.4	689.5	688.2	684.6	1	1971
1997	685.7	686.5	687.6	686.8	685.2	1	1970
1998	685.7	686.5	687.6	686.8	685.2	1	1970
1999	688.9	688.7	687.8	686.8	684.6	1	1969
2000	685.7	686.5	687.6	686.8	685.2	1	1970
2001	685.7	686.5	687.6	686.8	685.2	1	1970
2002	687.9	689.7	689.5	689.0	686.1	1	1967
2003	686.8	687.4	688.3	687.6	686.3	1	1968
2004	685.7	686.5	687.6	686.8	685.2	1	1970
2005	685.7	686.5	687.6	686.8	685.2	1	1970
2006	686.8	687.4	688.3	687.6	686.3	1	1968

(Continued on next page.)

Appendix 1. Continued.

Group Run C--Proposed Rochers River Constriction							
Year	Ecological Time Period					Trap	Year
	1	2	3	4	5	Code	Used
1971	684.5	686.0	687.0	686.0	684.0	0	----
1972	686.7	687.7	690.1	688.8	685.1	1	1971
1973	686.1	686.7	687.7	686.9	685.5	1	1970
1974	686.1	686.7	687.7	686.9	685.5	1	1970
1975	689.1	689.5	688.6	687.4	685.1	1	1969
1976	686.1	686.7	687.7	686.9	685.5	1	1970
1977	686.1	686.7	687.7	686.9	685.5	1	1970
1978	688.6	690.3	690.5	690.0	686.9	1	1967
1979	687.4	688.1	689.1	688.4	686.9	1	1968
1980	686.1	686.7	687.7	686.9	685.5	1	1970
1981	686.1	686.7	687.7	686.9	685.5	1	1970
1982	687.4	688.1	689.1	688.4	686.9	1	1968
1983	689.1	689.5	688.6	687.4	685.1	1	1969
1984	686.7	687.7	690.1	688.8	685.1	1	1971
1985	686.1	686.7	687.7	686.9	685.5	1	1970
1986	686.1	686.7	687.7	686.9	685.5	1	1970
1987	689.1	689.5	688.6	687.4	685.1	1	1969
1988	686.1	686.7	687.7	686.9	685.5	1	1970
1989	686.1	686.7	687.7	686.9	685.5	1	1970
1990	688.6	690.3	690.5	690.0	686.9	1	1967
1991	687.4	688.1	689.1	688.4	686.9	1	1968
1992	686.1	686.7	687.7	686.9	685.5	1	1970
1993	686.1	686.7	687.7	686.9	685.5	1	1970
1994	687.4	688.1	689.1	688.4	686.9	1	1968
1995	689.1	689.5	688.6	687.4	685.1	1	1969
1996	686.7	687.7	690.1	688.8	685.1	1	1971
1997	686.1	686.7	687.7	686.9	685.5	1	1970
1998	686.1	686.7	687.7	686.9	685.5	1	1970
1999	689.1	689.5	688.6	687.4	685.1	1	1969
2000	686.1	686.7	687.7	686.9	685.5	1	1970
2001	686.1	686.7	687.7	686.9	685.5	1	1970
2002	688.6	690.3	690.5	690.0	686.9	1	1967
2003	687.4	688.1	689.1	688.4	686.9	1	1968
2004	686.1	686.7	687.7	686.9	685.5	1	1970
2005	686.1	686.7	687.7	686.9	685.5	1	1970
2006	687.4	688.1	689.1	688.4	686.9	1	1968

(Continued on next page.)

Appendix 1. Continued.

Group Run C--Proposed Slave River Constriction

Year	Ecological Time Period					Trap	Year
	1	2	3	4	5	Code	Used
1971	684.5	686.0	687.0	686.0	684.0	0	----
1972	686.1	686.9	690.0	687.9	684.0	1	1971
1973	685.6	685.4	685.3	684.3	683.8	1	1970
1974	685.6	685.4	685.3	684.3	683.8	1	1970
1975	689.6	689.3	687.9	686.0	684.0	1	1969
1976	685.6	685.4	685.3	684.3	683.8	1	1970
1977	685.6	685.4	685.3	684.3	683.8	1	1970
1978	688.5	690.5	690.6	688.8	685.5	1	1967
1979	687.3	688.1	689.0	687.4	685.8	1	1968
1980	685.6	685.4	685.3	684.3	683.8	1	1970
1981	685.6	685.4	685.3	684.3	683.8	1	1970
1982	687.3	688.1	689.0	687.4	685.8	1	1968
1983	689.6	689.3	687.9	686.0	684.0	1	1969
1984	686.1	686.9	690.0	687.9	684.0	1	1971
1985	685.6	685.4	685.3	684.3	683.8	1	1970
1986	685.6	685.4	685.3	684.3	683.8	1	1970
1987	689.6	689.3	687.9	686.0	684.0	1	1969
1988	685.6	685.4	685.3	684.3	683.8	1	1970
1989	685.6	685.4	685.3	684.3	683.8	1	1970
1990	688.5	690.5	690.6	688.8	685.5	1	1967
1991	687.3	688.1	689.0	687.4	685.8	1	1968
1992	685.6	685.4	685.3	684.3	683.8	1	1970
1993	685.6	685.4	685.3	684.3	683.8	1	1970
1994	687.3	688.1	689.0	687.4	685.8	1	1968
1995	689.6	689.3	687.9	686.0	684.0	1	1969
1996	686.1	686.9	690.0	687.9	684.0	1	1971
1997	685.6	685.4	685.3	684.3	683.8	1	1970
1998	685.6	685.4	685.3	684.3	683.8	1	1970
1999	689.6	689.3	687.9	686.0	684.0	1	1969
2000	685.6	685.4	685.3	684.3	683.8	1	1970
2001	685.6	685.4	685.3	684.3	683.8	1	1970
2002	688.5	690.5	690.6	688.8	685.5	1	1967
2003	687.3	688.1	689.0	687.4	685.8	1	1968
2004	685.6	685.4	685.3	684.3	683.8	1	1970
2005	685.6	685.4	685.3	684.3	683.8	1	1970
2006	687.3	688.1	689.0	687.4	685.8	1	1968

(Continued on next page.)

Appendix 1. Continued.

Group Run E -- Natural Regime							
Year	Ecological Time Period					Trap	Year
	1	2	3	4	5	Code	Used
1971	684.5	686.0	687.0	686.0	684.0	0	----
1972	685.7	687.4	686.4	684.5	682.1	1	1969
1973	685.7	687.4	686.4	684.5	682.1	1	1969
1974	683.3	685.4	687.3	685.2	683.0	1	1970
1975	683.6	686.0	690.0	687.4	682.1	1	1971
1976	683.3	685.4	687.3	685.2	683.0	1	1970
1977	683.5	686.7	689.5	690.0	685.6	1	1964
1978	685.7	687.4	686.4	684.5	682.1	1	1969
1979	683.5	686.7	689.5	690.0	685.6	1	1964
1980	683.3	685.4	687.3	685.2	683.0	1	1970
1981	683.3	685.4	687.3	685.2	683.0	1	1970
1982	683.3	685.4	687.3	685.2	683.0	1	1970
1983	683.7	686.8	690.1	689.1	684.8	1	1962
1984	683.3	685.4	687.3	685.2	683.0	1	1970
1985	685.7	687.4	686.4	684.5	682.1	1	1969
1986	683.5	686.4	688.7	686.7	683.9	1	1968
1987	683.3	685.4	687.3	685.2	683.0	1	1970
1988	683.5	686.4	688.7	686.7	683.9	1	1968
1989	683.5	686.4	688.7	686.7	683.9	1	1968
1990	685.6	687.9	689.2	688.4	684.2	1	1966
1991	685.7	687.4	686.4	684.5	682.1	1	1969
1992	682.7	685.5	689.2	688.3	685.8	1	1960
1993	683.3	685.4	687.3	685.2	683.0	1	1970
1994	683.5	686.4	688.7	686.7	683.9	1	1968
1995	682.7	685.5	689.2	688.3	685.8	1	1960
1996	686.5	688.8	689.4	687.3	683.2	1	1963
1997	683.3	685.4	687.3	685.2	683.0	1	1970
1998	683.5	686.4	688.7	686.7	683.9	1	1968
1999	686.5	688.8	689.4	687.3	683.2	1	1963
2000	685.7	687.4	686.4	684.5	682.1	1	1969
2001	685.7	687.4	686.4	684.5	682.1	1	1969
2002	683.3	685.4	687.3	685.2	683.0	1	1970
2003	683.5	686.7	689.5	690.0	685.6	1	1964
2004	683.7	686.8	690.1	689.1	684.8	1	1962
2005	683.3	685.4	687.3	685.2	683.0	1	1970
2006	685.7	687.4	686.4	684.5	682.1	1	1969

(Continued on next page.)

Appendix 1. Continued.

Group Run E -- Modified Regime (Bennett Dam)							
Year	Ecological Time Period					Trap	Year
	1	2	3	4	5	Code	Used
1971	684.5	686.0	687.0	686.0	684.0	0	----
1972	687.6	687.2	685.9	684.2	682.5	1	1969
1973	687.6	687.2	685.9	684.2	682.5	1	1969
1974	684.1	684.1	684.4	683.3	682.7	1	1970
1975	684.6	685.4	687.9	686.0	683.9	1	1971
1976	684.1	684.1	684.4	683.3	682.7	1	1970
1977	685.2	686.3	686.2	686.7	685.2	1	1964
1978	687.6	687.2	685.9	684.2	682.5	1	1969
1979	685.2	686.3	686.2	686.7	685.2	1	1964
1980	684.1	684.1	684.4	683.3	682.7	1	1970
1981	684.1	684.1	684.4	683.3	682.7	1	1970
1982	684.1	684.1	684.4	683.3	682.7	1	1970
1983	685.5	687.4	688.3	687.7	684.8	1	1962
1984	684.1	684.1	684.4	683.3	682.7	1	1970
1985	687.6	687.2	685.9	684.2	682.5	1	1969
1986	685.4	686.0	686.8	685.5	684.2	1	1968
1987	684.1	684.1	684.4	683.3	682.7	1	1970
1988	685.4	686.0	686.8	685.5	684.2	1	1968
1989	685.4	686.0	686.8	685.5	684.2	1	1968
1990	687.0	688.0	687.5	687.0	684.5	1	1966
1991	687.6	687.2	685.9	684.2	682.5	1	1969
1992	683.9	685.4	686.9	686.6	685.7	1	1960
1993	684.1	684.1	684.4	683.3	682.7	1	1970
1994	685.4	686.0	686.8	685.5	684.2	1	1968
1995	683.9	685.4	686.9	686.6	685.7	1	1960
1996	687.4	688.4	687.5	686.1	683.5	1	1963
1997	684.1	684.1	684.4	683.3	682.7	1	1970
1998	685.4	686.0	686.8	685.5	684.2	1	1968
1999	687.4	688.4	687.5	686.1	683.5	1	1963
2000	687.6	687.2	685.9	684.2	682.5	1	1969
2001	687.6	687.2	685.9	684.2	682.5	1	1969
2002	684.1	684.1	684.4	683.3	682.7	1	1970
2003	685.2	686.3	686.2	686.7	685.2	1	1964
2004	685.5	687.4	688.3	687.7	684.8	1	1962
2005	684.1	684.1	684.4	683.3	682.7	1	1970
2006	687.6	687.2	685.9	684.2	682.5	1	1969

(Continued on next page.)

Appendix 1. Continued.

Group Run E -- Proposed Pochers Weir

Year	Ecological Time Period 1	2	3	4	5	Trap Code	Year Used
1971	684.5	686.0	687.0	686.0	684.0	0	----
1972	688.9	688.7	687.8	686.8	684.6	1	1969
1973	688.9	688.7	687.8	686.8	684.6	1	1969
1974	685.7	686.5	687.6	686.8	685.2	1	1970
1975	686.4	687.4	689.5	688.2	684.6	1	1971
1976	685.7	686.5	687.6	686.8	685.2	1	1970
1977	686.5	687.5	687.3	688.3	687.0	1	1964
1978	688.9	688.7	687.8	686.8	684.6	1	1969
1979	686.5	687.5	687.3	688.3	687.0	1	1964
1980	685.7	686.5	687.6	686.8	685.2	1	1970
1981	685.7	686.5	687.6	686.8	685.2	1	1970
1982	685.7	686.5	687.6	686.8	685.2	1	1970
1983	687.0	688.7	689.4	689.7	686.7	1	1962
1984	685.7	686.5	687.6	686.8	685.2	1	1970
1985	688.9	688.7	687.8	686.8	684.6	1	1969
1986	686.8	687.4	688.3	687.6	686.3	1	1968
1987	685.7	686.5	687.6	686.8	685.2	1	1970
1988	686.8	687.4	688.3	687.6	686.3	1	1968
1989	686.8	687.4	688.3	687.6	686.3	1	1968
1990	688.2	689.2	689.0	689.0	686.5	1	1966
1991	688.9	688.7	687.8	686.8	684.6	1	1969
1992	684.3	686.0	687.5	688.9	687.7	1	1960
1993	685.7	686.5	687.6	686.8	685.2	1	1970
1994	686.8	687.4	688.3	687.6	686.3	1	1968
1995	684.3	686.0	687.5	688.9	687.7	1	1960
1996	688.6	689.6	689.0	688.2	685.7	1	1963
1997	685.7	686.5	687.6	686.8	685.2	1	1970
1998	686.8	687.4	688.3	687.6	686.3	1	1968
1999	688.6	689.6	689.0	688.2	685.7	1	1963
2000	688.9	688.7	687.8	686.8	684.6	1	1969
2001	688.9	688.7	687.8	686.8	684.6	1	1969
2002	685.7	686.5	687.6	686.8	685.2	1	1970
2003	686.5	687.5	687.3	688.3	687.0	1	1964
2004	687.0	688.7	689.4	689.7	686.7	1	1962
2005	685.7	686.5	687.6	686.8	685.2	1	1970
2006	688.9	688.7	687.8	686.8	684.6	1	1969

(Continued on next page.)

Appendix 1. Continued.

Group Run E -- Proposed Rochers River Constriction							
Year	Ecological Time Period					Trap	Year
	1	1	3	4	5	Code	Used
1971	684.5	686.0	687.0	686.0	684.0	0	----
1972	689.1	689.5	688.6	687.4	685.1	1	1969
1973	689.1	689.5	688.6	687.4	685.1	1	1969
1974	686.1	686.7	687.7	686.9	685.5	1	1970
1975	686.7	687.7	690.1	688.8	685.1	1	1971
1976	686.1	686.7	687.7	686.9	685.5	1	1970
1977	687.1	688.2	688.1	689.0	687.7	1	1964
1978	689.1	689.5	688.6	687.4	685.1	1	1969
1979	687.1	688.2	688.1	689.0	687.7	1	1964
1980	686.1	686.7	687.7	686.9	685.5	1	1970
1981	686.1	686.7	687.7	686.9	685.5	1	1970
1982	686.1	686.7	687.7	686.9	685.5	1	1970
1983	687.3	689.2	690.1	690.5	687.6	1	1962
1984	686.1	686.7	687.7	686.9	685.5	1	1970
1985	689.1	689.5	688.6	687.4	685.1	1	1969
1986	687.4	688.1	689.1	688.4	686.9	1	1968
1987	686.1	686.7	687.7	686.9	685.5	1	1970
1988	687.4	688.1	689.1	688.4	686.9	1	1968
1989	687.4	688.1	689.1	688.4	686.9	1	1968
1990	688.9	689.9	689.9	690.2	687.4	1	1966
1991	689.1	689.5	688.6	687.4	685.1	1	1969
1992	684.3	686.0	687.7	689.3	688.2	1	1960
1993	686.1	686.7	687.7	686.9	685.5	1	1970
1994	687.4	688.1	689.1	688.4	686.9	1	1968
1995	684.3	686.0	687.7	689.3	688.2	1	1960
1996	689.2	690.4	689.9	689.2	686.4	1	1963
1997	686.1	686.7	687.7	686.9	685.5	1	1970
1998	687.4	688.1	689.1	688.4	686.9	1	1968
1999	689.2	690.4	689.9	689.2	686.4	1	1963
2000	689.1	689.5	688.6	687.4	685.1	1	1969
2001	689.1	689.5	688.6	687.4	685.1	1	1969
2002	686.1	686.7	687.7	686.9	685.5	1	1970
2003	687.1	688.2	688.1	689.0	687.7	1	1964
2004	687.3	689.2	690.1	690.5	687.6	1	1962
2005	686.1	686.7	687.7	686.9	685.5	1	1970
2006	689.1	689.5	688.6	687.4	685.1	1	1969

(Continued on next page.)

Appendix 1. Continued.

Group Run E -- Proposed Slave River Constriction							
Year	Ecological Time Period					Trap	Year
	1	2	3	4	5	Code	Used
1971	684.5	686.0	687.0	686.0	684.0	0	----
1972	689.6	689.3	687.9	686.0	684.0	1	1969
1973	689.6	689.3	687.9	686.0	684.0	1	1969
1974	685.6	685.4	685.3	684.3	683.8	1	1970
1975	686.1	686.9	690.0	687.9	684.0	1	1971
1976	685.6	685.4	685.3	684.3	683.8	1	1970
1977	686.9	688.2	688.4	689.1	687.1	1	1964
1978	689.6	689.3	687.9	686.0	684.0	1	1969
1979	686.9	688.2	688.4	689.1	687.1	1	1964
1980	685.6	685.4	685.3	684.3	683.8	1	1970
1981	685.6	685.4	685.3	684.3	683.8	1	1970
1982	685.6	685.4	685.3	684.3	683.8	1	1970
1983	687.2	689.3	690.6	689.9	686.7	1	1962
1984	685.6	685.4	685.3	684.3	683.8	1	1970
1985	689.6	689.3	687.9	686.0	684.0	1	1969
1986	687.3	688.1	689.0	687.4	685.8	1	1968
1987	685.6	685.4	685.3	684.3	683.8	1	1970
1988	687.3	688.1	689.0	687.4	685.8	1	1968
1989	687.3	688.1	689.0	687.4	685.8	1	1968
1990	689.3	690.2	689.7	689.1	686.2	1	1966
1991	689.6	689.3	687.9	686.0	684.0	1	1969
1992	684.9	686.7	688.7	688.3	687.3	1	1960
1993	685.6	685.4	685.3	684.3	683.8	1	1970
1994	687.3	688.1	689.0	687.4	685.8	1	1968
1995	684.9	686.7	688.7	688.3	687.3	1	1960
1996	689.5	690.7	689.8	688.2	685.3	1	1963
1997	685.6	685.4	685.3	684.3	683.8	1	1970
1998	687.3	688.1	689.0	687.4	685.8	1	1968
1999	689.5	690.7	689.8	688.2	685.3	1	1963
2000	689.6	689.3	687.9	686.0	684.0	1	1969
2001	689.6	689.3	687.9	686.0	684.0	1	1969
2002	685.6	685.4	685.3	684.3	683.8	1	1970
2003	686.9	688.2	688.4	689.1	687.1	1	1964
2004	687.2	689.3	690.6	689.9	686.7	1	1962
2005	685.6	685.4	685.3	684.3	683.8	1	1970
2006	689.6	689.3	687.9	686.0	684.0	1	1969

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Appendix 1. Continued.

Group Run F -- Natural Regime							
Year	Ecological Time Period					Trap	Year
	1	2	3	4	5	Code	Used
1971	684.5	686.0	687.0	686.0	684.0	0	----
1972	682.7	685.5	689.2	688.3	685.8	1	1960
1973	685.9	688.3	689.1	686.3	682.1	1	1961
1974	683.7	686.8	690.1	689.1	684.8	1	1962
1975	686.5	688.8	689.4	687.3	683.2	1	1963
1976	683.5	686.7	689.5	690.0	685.6	1	1964
1977	686.5	688.9	691.4	689.2	684.9	1	1965
1978	685.6	687.9	689.2	688.4	684.2	1	1966
1979	684.9	688.6	690.4	688.1	683.5	1	1967
1980	683.5	686.4	688.7	686.7	683.9	1	1968
1981	685.7	687.4	686.4	684.5	682.1	1	1969
1982	686.5	688.9	691.4	689.2	684.9	1	1965
1983	686.5	688.9	691.4	689.2	684.9	1	1965
1984	683.5	686.4	688.7	686.7	683.9	1	1968
1985	683.3	685.4	687.3	685.2	683.0	1	1970
1986	683.3	685.4	687.3	685.2	683.0	1	1970
1987	685.7	687.4	686.4	684.5	682.1	1	1969
1988	683.3	685.4	687.3	685.2	683.0	1	1970
1989	683.5	686.4	688.7	686.7	683.9	1	1968
1990	683.5	686.4	688.7	686.7	683.9	1	1968
1991	683.3	685.4	687.3	685.2	683.0	1	1970
1992	685.7	687.4	686.4	684.5	682.1	1	1969
1993	683.3	685.4	687.3	685.2	683.0	1	1970
1994	685.7	687.4	686.4	684.5	682.1	1	1969
1995	683.6	686.0	690.0	687.4	682.1	1	1971
1996	683.3	685.4	687.3	685.2	683.0	1	1970
1997	683.3	685.4	687.3	685.2	683.0	1	1970
1998	685.7	687.4	686.4	684.5	682.1	1	1969
1999	683.3	685.4	687.3	685.2	683.0	1	1970
2000	683.3	685.4	687.3	685.2	683.0	1	1970
2001	684.9	688.6	690.4	688.1	683.5	1	1967
2002	683.5	686.4	688.7	686.7	683.9	1	1968
2003	683.3	685.4	687.3	685.2	683.0	1	1970
2004	683.3	685.4	687.3	685.2	683.0	1	1970
2005	683.5	686.4	688.7	686.7	683.9	1	1968
2006	685.7	687.4	686.4	684.5	682.1	1	1969

(Continued on next page.)

Appendix 1. Continued.

Group Run F -- Modified Regime (Bennett Dam)							
Year	Ecological Time Period					Trap	Year
	1	2	3	4	5	Code	Used
1971	684.5	686.0	687.0	686.0	684.0	0	----
1972	683.9	685.4	686.9	686.6	685.7	1	1960
1973	687.3	687.0	686.4	685.0	682.6	1	1961
1974	685.5	687.4	688.3	687.7	684.8	1	1962
1975	687.4	688.4	687.5	686.1	683.5	1	1963
1976	685.2	686.3	686.2	686.7	685.2	1	1964
1977	687.7	688.6	689.3	687.9	685.2	1	1965
1978	687.0	688.0	687.5	687.0	684.5	1	1966
1979	686.6	688.5	688.1	686.8	683.9	1	1967
1980	685.4	686.0	686.8	685.5	684.2	1	1968
1981	687.6	687.2	685.9	684.2	682.5	1	1969
1982	687.7	688.6	689.3	687.9	685.2	1	1965
1983	687.7	688.6	689.3	687.9	685.2	1	1965
1984	685.4	686.0	686.8	685.5	684.2	1	1968
1985	684.1	684.1	684.4	683.3	682.7	1	1970
1986	684.1	684.1	684.4	683.3	682.7	1	1970
1987	687.6	687.2	685.9	684.2	682.5	1	1969
1988	684.1	684.1	684.4	683.3	682.7	1	1970
1989	685.4	686.0	686.8	685.5	684.2	1	1968
1990	685.4	686.0	686.8	685.5	684.2	1	1968
1991	684.1	684.1	684.4	683.3	682.7	1	1970
1992	687.6	687.2	685.9	684.2	682.5	1	1969
1993	684.1	684.1	684.4	683.3	682.7	1	1970
1994	687.6	687.2	685.9	684.2	682.5	1	1969
1995	684.6	685.4	687.9	686.0	683.9	1	1971
1996	684.1	684.1	684.4	683.3	682.7	1	1970
1997	684.1	684.1	684.4	683.3	682.7	1	1970
1998	687.6	687.2	685.9	684.2	682.5	1	1969
1999	684.1	684.1	684.4	683.3	682.7	1	1970
2000	684.1	684.1	684.4	683.3	682.7	1	1970
2001	686.6	688.5	688.1	686.8	683.9	1	1967
2002	685.4	686.0	686.8	685.5	684.2	1	1968
2003	684.1	684.1	684.4	683.3	682.7	1	1970
2004	684.1	684.1	684.4	683.3	682.7	1	1970
2005	685.4	686.0	686.8	685.5	684.2	1	1968
2006	687.6	687.2	685.9	684.2	682.5	1	1969

(Continued on next page.)

Appendix 1. Continued.

Group Run G -- Natural Regime							
Year	Ecological Time Period					Trap	Year
	1	2	3	4	5	Code	Used
1971	684.5	686.0	687.0	686.0	684.0	0	----
1972	682.7	685.5	689.2	688.3	685.8	1	1960
1973	685.9	688.3	689.1	686.3	682.1	1	1961
1974	683.7	686.8	690.1	689.1	684.8	1	1962
1975	686.5	688.8	689.4	687.3	683.2	1	1963
1976	683.5	686.7	689.5	690.0	685.6	1	1964
1977	686.5	688.9	691.4	689.2	684.9	1	1965
1978	685.6	687.9	689.2	688.4	684.2	1	1966
1979	684.9	688.6	690.4	688.1	683.5	1	1967
1980	683.5	686.4	688.7	686.7	683.9	1	1968
1981	685.7	687.4	686.4	684.5	682.1	1	1969
1982	686.5	688.9	691.4	689.2	684.9	1	1965
1983	686.5	688.9	691.4	689.2	684.9	1	1965
1984	683.5	686.4	688.7	686.7	683.9	1	1968
1985	683.3	685.4	687.3	685.2	683.0	1	1970
1986	683.3	685.4	687.3	685.2	683.0	1	1970
1987	685.7	687.4	686.4	684.5	682.1	1	1969
1988	683.3	685.4	687.3	685.2	683.0	1	1970
1989	683.5	686.4	688.7	686.7	683.9	1	1968
1990	683.5	686.4	688.7	686.7	683.9	1	1968
1991	683.3	685.4	687.3	685.2	683.0	1	1970
1992	685.7	687.4	686.4	684.5	682.1	1	1969
1993	683.3	685.4	687.3	685.2	683.0	1	1970
1994	685.7	687.4	686.4	684.5	682.1	1	1969
1995	683.6	686.0	690.0	687.4	682.1	1	1971
1996	683.3	685.4	687.3	685.2	683.0	1	1970
1997	683.3	685.4	687.3	685.2	683.0	1	1970
1998	685.7	687.4	686.4	684.5	682.1	1	1969
1999	683.3	685.4	687.3	685.2	683.0	1	1970
2000	683.3	685.4	687.3	685.2	683.0	1	1970
2001	684.9	688.6	690.4	688.1	683.5	1	1967
2002	683.5	686.4	688.7	686.7	683.9	1	1968
2003	683.3	685.4	687.3	685.2	683.0	1	1970
2004	683.3	685.4	687.3	685.2	683.0	1	1970
2005	683.5	686.4	688.7	686.7	683.9	1	1968

(Continued on next page.)

Appendix 1. Continued.

Group Run G -- Natural Regime (continued).

Year	Ecological Time Period					Trap	Year
	1	2	3	4	5	Code	Used
2006	685.7	687.4	686.4	684.5	682.1	1	1969
2007	684.9	688.6	690.4	688.1	683.5	1	1967
2008	685.7	687.4	686.4	684.5	682.1	1	1969
2009	683.5	686.4	688.7	686.7	683.9	1	1968
2010	686.5	688.8	689.4	687.3	683.2	1	1963
2011	683.3	685.4	687.3	685.2	683.0	1	1970
2012	683.3	685.4	687.3	685.2	683.0	1	1970
2013	685.7	687.4	686.4	684.5	682.1	1	1969
2014	683.3	685.4	687.3	685.2	683.0	1	1970
2015	686.5	688.9	691.4	689.2	684.9	1	1965
2016	685.7	687.4	686.4	684.5	682.1	1	1969
2017	683.3	685.4	687.3	685.2	683.0	1	1970
2018	686.5	688.8	689.4	687.3	683.2	1	1963
2019	685.7	687.4	686.4	684.5	682.1	1	1969
2020	683.5	686.4	688.7	686.7	683.9	1	1968
2021	685.7	687.4	686.4	684.5	682.1	1	1969
2022	685.7	687.4	686.4	684.5	682.1	1	1969
2023	685.7	687.4	686.4	684.5	682.1	1	1969
2024	683.5	686.4	688.7	686.7	683.9	1	1968
2025	685.7	687.4	686.4	684.5	682.1	1	1969
2026	686.5	688.9	691.4	689.2	684.9	1	1965
2027	684.9	688.6	690.4	688.1	683.5	1	1967
2028	686.5	688.8	689.4	687.3	683.2	1	1963
2029	683.3	685.4	687.3	685.2	683.0	1	1970
2030	685.7	687.4	686.4	684.5	682.1	1	1969
2031	683.5	686.4	688.7	686.7	683.9	1	1968
2032	683.5	686.4	688.7	686.7	683.9	1	1968
2033	685.7	687.4	686.4	684.5	682.1	1	1969
2034	683.3	685.4	687.3	685.2	683.0	1	1970
2035	683.3	685.4	687.3	685.2	683.0	1	1970
2036	685.7	687.4	686.4	684.5	682.1	1	1969
2037	683.3	685.4	687.3	685.2	683.0	1	1970
2038	683.3	685.4	687.3	685.2	683.0	1	1970
2039	683.3	685.4	687.3	685.2	683.0	1	1970
2040	683.3	685.4	687.3	685.2	683.0	1	1970
2041	683.3	685.4	687.3	685.2	683.0	1	1970

(Continued on next page.)

Appendix 1. Continued.

Group Run G -- Modified Regime (Bennett Dam)							
Year	Ecological Time Period					Trap	Year
	1	2	3	4	5	Code	Used
1971	684.5	686.0	687.0	686.0	684.0	0	----
1972	683.9	685.4	686.9	686.6	685.7	1	1960
1973	687.3	687.0	686.4	685.0	682.6	1	1961
1974	685.5	687.4	688.3	687.7	684.8	1	1962
1975	687.4	688.4	687.5	686.1	683.5	1	1963
1976	685.2	686.3	686.2	686.7	685.2	1	1964
1977	687.7	688.6	689.3	687.9	685.2	1	1965
1978	687.0	688.0	687.5	687.0	684.5	1	1966
1979	686.6	688.5	688.1	686.8	683.9	1	1967
1980	685.4	686.0	686.8	685.5	684.2	1	1968
1981	687.6	687.2	685.9	684.2	682.5	1	1969
1982	687.7	688.6	689.3	687.9	685.2	1	1965
1983	687.7	688.6	689.3	687.9	685.2	1	1965
1984	685.4	686.0	686.8	685.5	684.2	1	1968
1985	684.1	684.1	684.4	683.3	682.7	1	1970
1986	684.1	684.1	684.4	683.3	682.7	1	1970
1987	687.6	687.2	685.9	684.2	682.5	1	1969
1988	684.1	684.1	684.4	683.3	682.7	1	1970
1989	685.4	686.0	686.8	685.5	684.2	1	1968
1990	685.4	686.0	686.8	685.5	684.2	1	1968
1991	684.1	684.1	684.4	683.3	682.7	1	1970
1992	687.6	687.2	685.9	684.2	682.5	1	1969
1993	684.1	684.1	684.4	683.3	682.7	1	1970
1994	687.6	687.2	685.9	684.2	682.5	1	1969
1995	684.6	685.4	687.9	686.0	683.9	1	1971
1996	684.1	684.1	684.4	683.3	682.7	1	1970
1997	684.1	684.1	684.4	683.3	682.7	1	1970
1998	687.6	687.2	685.9	684.2	682.5	1	1969
1999	684.1	684.1	684.4	683.3	682.7	1	1970
2000	684.1	684.1	684.4	683.3	682.7	1	1970
2001	686.6	688.5	688.1	686.8	683.9	1	1967
2002	685.4	686.0	686.8	685.5	684.2	1	1968
2003	684.1	684.1	684.4	683.3	682.7	1	1970
2004	684.1	684.1	684.4	683.3	682.7	1	1970
2005	685.4	686.0	686.8	685.5	684.2	1	1968

(Continued on next page.)

Appendix 1. Continued.

Group Run G -- Modified Regime (Bennett Dam) (continued).							
Year	Ecological Time Period					Trap	Year
	1	2	3	4	5	Code	Used
2006	687.6	687.2	685.9	684.2	682.5	1	1969
2007	686.6	688.5	688.1	686.8	683.9	1	1967
2008	687.6	687.2	685.9	684.2	682.5	1	1969
2009	685.4	686.0	686.8	685.5	684.2	1	1968
2010	687.4	688.4	687.5	686.1	683.5	1	1963
2011	684.1	684.1	684.4	683.3	682.7	1	1970
2012	684.1	684.1	684.4	683.3	682.7	1	1970
2013	687.6	687.2	685.9	684.2	682.5	1	1969
2014	684.1	684.1	684.4	683.3	682.7	1	1970
2015	687.7	688.6	689.3	687.9	685.2	1	1965
2016	687.6	687.2	685.9	684.2	682.5	1	1969
2017	684.1	684.1	684.4	683.3	682.7	1	1970
2018	687.4	688.4	687.5	686.1	683.5	1	1963
2019	687.6	687.2	685.9	684.2	682.5	1	1969
2020	685.4	686.0	686.8	685.5	684.2	1	1968
2021	687.6	687.2	685.9	684.2	682.5	1	1969
2022	687.6	687.2	685.9	684.2	682.5	1	1969
2023	687.6	687.2	685.9	684.2	682.5	1	1969
2024	685.4	686.0	686.8	685.5	684.2	1	1968
2025	687.6	687.2	685.9	684.2	682.5	1	1969
2026	687.7	688.6	689.3	687.9	685.2	1	1965
2027	686.6	688.5	688.1	686.8	683.9	1	1967
2028	687.4	688.4	687.5	686.1	683.5	1	1963
2029	684.1	684.1	684.4	683.3	682.7	1	1970
2030	687.6	687.2	685.9	684.2	682.5	1	1969
2031	685.4	686.0	686.8	685.5	684.2	1	1968
2032	685.4	686.0	686.8	685.5	684.2	1	1968
2033	687.6	687.2	685.9	684.2	682.5	1	1969
2034	684.1	684.1	684.4	683.3	682.7	1	1970
2035	684.1	684.1	684.4	683.3	682.7	1	1970
2036	687.6	687.2	685.9	684.2	682.5	1	1969
2037	684.1	684.1	684.4	683.3	682.7	1	1970
2038	684.1	684.1	684.4	683.3	682.7	1	1970
2039	684.1	684.1	684.4	683.3	682.7	1	1970
2040	684.1	684.1	684.4	683.3	682.7	1	1970
2041	684.1	684.1	684.4	683.3	682.7	1	1970

(Continued on next page.)

Appendix 1. Continued.

Group Run H -- Natural Regime							
Year	Ecological Time Period					Trap	Year
	1	2	3	4	5	Code	Used
1971	684.5	686.0	687.0	686.0	684.0	0	----
1972	685.7	687.4	686.4	684.5	682.1	1	1969
1973	685.7	687.4	686.4	684.5	682.1	1	1969
1974	683.3	685.4	687.3	685.2	683.0	1	1970
1975	683.6	686.0	690.0	687.4	682.1	1	1971
1976	683.3	685.4	687.3	685.2	683.0	1	1970
1977	683.5	686.7	689.5	690.0	685.6	1	1964
1978	685.7	687.4	686.4	684.5	682.1	1	1969
1979	683.5	686.7	689.5	690.0	685.6	1	1964
1980	683.3	685.4	687.3	685.2	683.0	1	1970
1981	683.3	685.4	687.3	685.2	683.0	1	1970
1982	683.3	685.4	687.3	685.2	683.0	1	1970
1983	683.7	686.8	690.1	689.1	684.8	1	1962
1984	683.3	685.4	687.3	685.2	683.0	1	1970
1985	685.7	687.4	686.4	684.5	682.1	1	1969
1986	683.5	686.4	688.7	686.7	683.9	1	1968
1987	683.3	685.4	687.3	685.2	683.0	1	1970
1988	683.5	686.4	688.7	686.7	683.9	1	1968
1989	683.5	686.4	688.7	686.7	683.9	1	1968
1990	685.6	687.9	689.2	688.4	684.2	1	1966
1991	685.7	687.4	686.4	684.5	682.1	1	1969
1992	682.7	685.5	689.2	688.3	685.8	1	1960
1993	683.3	685.4	687.3	685.2	683.0	1	1970
1994	683.5	686.4	688.7	686.7	683.9	1	1968
1995	682.7	685.5	689.2	688.3	685.8	1	1960
1996	686.5	688.8	689.4	687.3	683.2	1	1963
1997	683.3	685.4	687.3	685.2	683.0	1	1970
1998	683.5	686.4	688.7	686.7	683.9	1	1968
1999	686.5	688.8	689.4	687.3	683.2	1	1963
2000	685.7	687.4	686.4	684.5	682.1	1	1969
2001	685.7	687.4	686.4	684.5	682.1	1	1969
2002	683.3	685.4	687.3	685.2	683.0	1	1970
2003	683.5	686.7	689.5	690.0	685.6	1	1964
2004	683.7	686.8	690.1	689.1	684.8	1	1962
2005	683.3	685.4	687.3	685.2	683.0	1	1970

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Appendix 1. Continued.

Group Run H -- Natural Regime (continued).							
Year	Ecological Time Period					Trap	Year
	1	2	3	4	5	Code	Used
2006	685.7	687.4	686.4	684.5	682.1	1	1969
2007	684.9	688.6	690.4	688.1	683.5	1	1967
2008	685.7	687.4	686.4	684.5	682.1	1	1969
2009	683.5	686.4	688.7	686.7	683.9	1	1968
2010	686.5	688.8	689.4	687.3	683.2	1	1963
2011	683.3	685.4	687.3	685.2	683.0	1	1970
2012	683.3	685.4	687.3	685.2	683.0	1	1970
2013	685.7	687.4	686.4	684.5	682.1	1	1969
2014	683.3	685.4	687.3	685.2	683.0	1	1970
2015	686.5	688.9	691.4	689.2	684.9	1	1965
2016	685.7	687.4	686.4	684.5	682.1	1	1969
2017	683.3	685.4	687.3	685.2	683.0	1	1970
2018	686.5	688.8	689.4	687.3	683.2	1	1963
2019	685.7	687.4	686.4	684.5	682.1	1	1969
2020	683.5	686.4	688.7	686.7	683.9	1	1968
2021	685.7	687.4	686.4	684.5	682.1	1	1969
2022	685.7	687.4	686.4	684.5	682.1	1	1969
2023	685.7	687.4	686.4	684.5	682.1	1	1969
2024	683.5	686.4	688.7	686.7	683.9	1	1968
2025	685.7	687.4	686.4	684.5	682.1	1	1969
2026	686.5	688.9	691.4	689.2	684.9	1	1965
2027	684.9	688.6	690.4	688.1	683.5	1	1967
2028	686.5	688.8	689.4	687.3	683.2	1	1963
2029	683.3	685.4	687.3	685.2	683.0	1	1970
2030	685.7	687.4	686.4	684.5	682.1	1	1969
2031	683.5	686.4	688.7	686.7	683.9	1	1968
2032	683.5	686.4	688.7	686.7	683.9	1	1968
2033	685.7	687.4	686.4	684.5	682.1	1	1969
2034	683.3	685.4	687.3	685.2	683.0	1	1970
2035	683.3	685.4	687.3	685.2	683.0	1	1970
2036	685.7	687.4	686.4	684.5	682.1	1	1969
2037	683.3	685.4	687.3	685.2	683.0	1	1970
2038	683.3	685.4	687.3	685.2	683.0	1	1970
2039	683.3	685.4	687.3	685.2	683.0	1	1970
2040	683.3	685.4	687.3	685.2	683.0	1	1970
2041	683.3	685.4	687.3	685.2	683.0	1	1970

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Appendix 1. Continued.

Group Run H -- Modified Regime (Bennett Dam)							
Year	Ecological Time Period					Trap	Year
	1	2	3	4	5	Code	Used
1971	684.5	686.0	687.0	686.0	684.0	0	----
1972	687.6	687.2	685.9	684.2	682.5	1	1969
1973	687.6	687.2	685.9	684.2	682.5	1	1969
1974	684.1	684.1	684.4	683.3	682.7	1	1970
1975	684.6	685.4	687.9	686.0	683.9	1	1971
1976	684.1	684.1	684.4	683.3	682.7	1	1970
1977	685.2	686.3	686.2	686.7	685.2	1	1964
1978	687.6	687.2	685.9	684.2	682.5	1	1969
1979	685.2	686.3	686.2	686.7	685.2	1	1964
1980	684.1	684.1	684.4	683.3	682.7	1	1970
1981	684.1	684.1	684.4	683.3	682.7	1	1970
1982	684.1	684.1	684.4	683.3	682.7	1	1970
1983	685.5	687.4	688.3	687.7	684.8	1	1962
1984	684.1	684.1	684.4	683.3	682.7	1	1970
1985	687.6	687.2	685.9	684.2	682.5	1	1969
1986	685.4	686.0	686.8	685.5	684.2	1	1968
1987	684.1	684.1	684.4	683.3	682.7	1	1970
1988	685.4	686.0	686.8	685.5	684.2	1	1968
1989	685.4	686.0	686.8	685.5	684.2	1	1968
1990	687.0	688.0	687.5	687.0	684.5	1	1966
1991	687.6	687.2	685.9	684.2	682.5	1	1969
1992	683.9	685.4	686.9	686.6	685.7	1	1960
1993	684.1	684.1	684.4	683.3	682.7	1	1970
1994	685.4	686.0	686.8	685.5	684.2	1	1968
1995	683.9	685.4	686.9	686.6	685.7	1	1960
1996	687.4	688.4	687.5	686.1	683.5	1	1963
1997	684.1	684.1	684.4	683.3	682.7	1	1970
1998	685.4	686.0	686.8	685.5	684.2	1	1968
1999	687.4	688.4	687.5	686.1	683.5	1	1963
2000	687.6	687.2	685.9	684.2	682.5	1	1969
2001	687.6	687.2	685.9	684.2	682.5	1	1969
2002	684.1	684.1	684.4	683.3	682.7	1	1970
2003	685.2	686.3	686.2	686.7	685.2	1	1964
2004	685.5	687.4	688.3	687.7	684.8	1	1962
2005	684.1	684.1	684.4	683.3	682.7	1	1970

(Continued on next page.)

Appendix 1. Continued.

Group Run H -- Modified Regime (Bennett Dam) (continued).

Year	Ecological Time Period					Trap	Year
	1	2	3	4	5	Code	Used
2006	687.6	687.2	685.9	684.2	682.5	1	1969
2007	686.6	688.5	688.1	686.8	683.9	1	1967
2008	687.6	687.2	685.9	684.2	682.5	1	1969
2009	685.4	686.0	686.8	685.5	684.2	1	1968
2010	687.4	688.4	687.5	686.1	683.5	1	1963
2011	684.1	684.1	684.4	683.3	682.7	1	1970
2012	684.1	684.1	684.4	683.3	682.7	1	1970
2013	687.6	687.2	685.9	684.2	682.5	1	1969
2014	684.1	684.1	684.4	683.3	682.7	1	1970
2015	687.7	688.6	689.3	687.9	685.2	1	1965
2016	687.6	687.2	685.9	684.2	682.5	1	1969
2017	684.1	684.1	684.4	683.3	682.7	1	1970
2018	687.4	688.4	687.5	686.1	683.5	1	1963
2019	687.6	687.2	685.9	684.2	682.5	1	1969
2020	685.4	686.0	686.8	685.5	684.2	1	1968
2021	687.6	687.2	685.9	684.2	682.5	1	1969
2022	687.6	687.2	685.9	684.2	682.5	1	1969
2023	687.6	687.2	685.9	684.2	682.5	1	1969
2024	685.4	686.0	686.8	685.5	684.2	1	1968
2025	687.6	687.2	685.9	684.2	682.5	1	1969
2026	687.7	688.6	689.3	687.9	685.2	1	1965
2027	686.6	688.5	688.1	686.8	683.9	1	1967
2028	687.4	688.4	687.5	686.1	683.5	1	1963
2029	684.1	684.1	684.4	683.3	682.7	1	1970
2030	687.6	687.2	685.9	684.2	682.5	1	1969
2031	685.4	686.0	686.8	685.5	684.2	1	1968
2032	685.4	686.0	686.8	685.5	684.2	1	1968
2033	687.6	687.2	685.9	684.2	682.5	1	1969
2034	684.1	684.1	684.4	683.3	682.7	1	1970
2035	684.1	684.1	684.4	683.3	682.7	1	1970
2036	687.6	687.2	685.9	684.2	682.5	1	1969
2037	684.1	684.1	684.4	683.3	682.7	1	1970
2038	684.1	684.1	684.4	683.3	682.7	1	1970
2039	684.1	684.1	684.4	683.3	682.7	1	1970
2040	684.1	684.1	684.4	683.3	682.7	1	1970
2041	684.1	684.1	684.4	683.3	682.7	1	1970

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Appendix 1. Continued.

Group Run I--Water Levels for Figures 6-10							
Year	Ecological Time Period					Trap	Not
	1	2	3	4	5	Code	Used
1971	684.5	686.0	687.0	686.0	684.0	0	0
1972	686.0	691.4	689.3	688.5	688.5	0	0
1973	688.0	688.5	688.5	688.0	688.0	0	0
1974	688.5	689.5	692.0	689.0	688.5	1	0
1975	689.0	689.5	691.0	688.5	687.0	1	0
1976	684.3	685.0	685.0	685.0	684.0	1	0
1977	684.3	685.0	685.5	685.0	684.0	1	0
1978	684.3	685.0	685.5	685.0	684.0	1	0
1979	684.3	685.0	685.5	685.0	684.0	1	0
1980	684.3	687.8	691.5	688.5	685.0	1	0
1981	685.5	686.0	687.0	687.0	687.0	1	0
1982	687.0	687.5	687.8	687.0	687.0	1	0
1983	687.0	687.6	687.0	687.0	686.5	1	0
1984	686.5	687.0	687.5	687.0	686.5	1	0
1985	686.5	687.0	687.5	687.0	686.5	1	0

(Continued on next page.)

Appendix 1. Continued.

Group Run A--Regulated with Ice Dam Every 4 Years							
Year	Ecological Time Period					Trap	Year
	1	2	3	4	5	Code	Used
1971	684.5	686.0	687.0	686.0	684.0	0	----
1972	686.5	688.5	692.2	688.9	685.7	1	ICE DAM
1973	687.7	688.6	689.3	687.9	685.2	1	1965
1974	685.4	686.0	686.8	685.5	684.2	1	1968
1975	684.1	684.1	684.4	683.3	682.7	1	1970
1976	686.5	688.5	692.2	688.9	685.7	1	ICE DAM
1977	687.6	687.2	685.9	684.2	682.5	1	1969
1978	684.1	684.1	684.4	683.3	682.7	1	1970
1979	685.4	686.0	686.8	685.5	684.2	1	1968
1980	686.5	688.5	692.2	688.9	685.7	1	ICE DAM
1981	684.1	684.1	684.4	683.3	682.7	1	1970
1982	687.6	687.2	685.9	684.2	682.5	1	1969
1983	684.1	684.1	684.4	683.3	682.7	1	1970
1984	686.5	688.5	692.2	688.9	685.7	1	ICE DAM
1985	684.6	685.4	687.9	686.0	683.9	1	1971
1986	684.1	684.1	684.4	683.3	682.7	1	1970
1987	684.1	684.1	684.4	683.3	682.7	1	1970
1988	686.5	688.5	692.2	688.9	685.7	1	ICE DAM
1989	684.1	684.1	684.4	683.3	682.7	1	1970
1990	684.1	684.1	684.4	683.3	682.7	1	1970
1991	686.6	688.5	688.1	686.8	683.9	1	1967
1992	686.5	688.5	692.2	688.9	685.7	1	ICE DAM
1993	684.1	684.1	684.4	683.3	682.7	1	1970
1994	684.1	684.1	684.4	683.3	682.7	1	1970
1995	685.4	686.0	686.8	685.5	684.2	1	1968
1996	686.5	688.5	692.2	688.9	685.7	1	ICE DAM
1997	683.9	685.4	686.9	686.6	685.7	1	1960
1998	687.3	687.0	686.4	685.0	682.6	1	1961
1999	685.5	687.4	688.3	687.7	684.8	1	1962
2000	686.5	688.5	692.2	688.9	685.7	1	ICE DAM
2001	685.2	686.3	686.2	686.7	685.2	1	1964
2002	687.7	688.6	689.3	687.9	685.2	1	1965
2003	687.0	688.0	687.5	687.0	684.5	1	1966
2004	686.5	688.5	692.2	688.9	685.7	1	ICE DAM
2005	685.4	686.0	686.8	685.5	684.2	1	1968
2006	687.6	687.2	685.9	684.2	682.5	1	1969

(Continued on next page.)

Appendix 1. Continued.

Group Run A--Regulated with Ice Dam Every 5 Years							
Year	Ecological Time Period					Trap	Year
	1	2	3	4	5	Code	Used
1971	684.5	686.0	687.0	686.0	684.0	0	----
1972	686.5	688.5	692.2	688.9	685.7	1	ICE DAM
1973	687.7	688.6	689.3	687.9	685.2	1	1965
1974	685.4	686.0	686.8	685.5	684.2	1	1968
1975	684.1	684.1	684.4	683.3	682.7	1	1970
1976	684.1	684.1	684.4	683.3	682.7	1	1970
1977	686.5	688.5	692.2	688.9	685.7	1	ICE DAM
1978	684.1	684.1	684.4	683.3	682.7	1	1970
1979	685.4	686.0	686.8	685.5	684.2	1	1968
1980	685.4	686.0	686.8	685.5	684.2	1	1968
1981	684.1	684.1	684.4	683.3	682.7	1	1970
1982	686.5	688.5	692.2	688.9	685.7	1	ICE DAM
1983	684.1	684.1	684.4	683.3	682.7	1	1970
1984	687.6	687.2	685.9	684.2	682.5	1	1969
1985	684.6	685.4	687.9	686.0	683.9	1	1971
1986	684.1	684.1	684.4	683.3	682.7	1	1970
1987	686.5	688.5	692.2	688.9	685.7	1	ICE DAM
1988	687.6	687.2	685.9	684.2	682.5	1	1969
1989	684.1	684.1	684.4	683.3	682.7	1	1970
1990	684.1	684.1	684.4	683.3	682.7	1	1970
1991	686.6	688.5	688.1	686.8	683.9	1	1967
1992	686.5	688.5	692.2	688.9	685.7	1	ICE DAM
1993	684.1	684.1	684.4	683.3	682.7	1	1970
1994	684.1	684.1	684.4	683.3	682.7	1	1970
1995	685.4	686.0	686.8	685.5	684.2	1	1968
1996	687.6	687.2	685.9	684.2	682.5	1	1969
1997	686.5	688.5	692.2	688.9	685.7	1	ICE DAM
1998	687.3	687.0	686.4	685.0	682.6	1	1961
1999	685.5	687.4	688.3	687.7	684.8	1	1962
2000	687.4	688.4	687.5	686.1	683.5	1	1963
2001	685.2	686.3	686.2	686.7	685.2	1	1964
2002	686.5	688.5	692.2	688.9	685.7	1	ICE DAM
2003	687.0	688.0	687.5	687.0	684.5	1	1966
2004	686.6	688.5	688.1	686.8	683.9	1	1967
2005	685.4	686.0	686.8	685.5	684.2	1	1968
2006	687.6	687.2	685.9	684.2	682.5	1	1969

(Continued on next page.)

Appendix 1. Continued.

Group Run A--Regulated with Ice Dam Every 6 Years							
Year	Ecological Time Period					Trap	Year
	1	2	3	4	5	Code	Used
1971	684.5	686.0	687.0	686.0	684.0	0	----
1972	686.5	688.5	692.2	688.9	685.7	1	ICE DAM
1973	687.7	688.6	689.3	687.9	685.2	1	1965
1974	685.4	686.0	686.8	685.5	684.2	1	1968
1975	684.1	684.1	684.4	683.3	682.7	1	1970
1976	684.1	684.1	684.4	683.3	682.7	1	1970
1977	687.6	687.2	685.9	684.2	682.5	1	1969
1978	686.5	688.5	692.2	688.9	685.7	1	ICE DAM
1979	685.4	686.0	686.8	685.5	684.2	1	1968
1980	685.4	686.0	686.8	685.5	684.2	1	1968
1981	684.1	684.1	684.4	683.3	682.7	1	1970
1982	687.6	687.2	685.9	684.2	682.5	1	1969
1983	684.1	684.1	684.4	683.3	682.7	1	1970
1984	686.5	688.5	692.2	688.9	685.7	1	ICE DAM
1985	684.6	685.4	687.9	686.0	683.9	1	1971
1986	684.1	684.1	684.4	683.3	682.7	1	1970
1987	684.1	684.1	684.4	683.3	682.7	1	1970
1988	687.6	687.2	685.9	684.2	682.5	1	1969
1989	684.1	684.1	684.4	683.3	682.7	1	1970
1990	686.5	688.5	692.2	688.9	685.7	1	ICE DAM
1991	686.6	688.5	688.1	686.8	683.9	1	1967
1992	685.4	686.0	686.8	685.5	684.2	1	1968
1993	684.1	684.1	684.4	683.3	682.7	1	1970
1994	684.1	684.1	684.4	683.3	682.7	1	1970
1995	685.4	686.0	686.8	685.5	684.2	1	1968
1996	686.5	688.5	692.2	688.9	685.7	1	ICE DAM
1997	683.9	685.4	686.9	686.6	685.7	1	1960
1998	687.3	687.0	686.4	685.0	682.6	1	1961
1999	685.5	687.4	688.3	687.7	684.8	1	1962
2000	687.4	688.4	687.5	686.1	683.5	1	1963
2001	685.2	686.3	686.2	686.7	685.2	1	1964
2002	686.5	688.5	692.2	688.9	685.7	1	ICE DAM
2003	687.0	688.0	687.5	687.0	684.5	1	1966
2004	686.6	688.5	688.1	686.8	683.9	1	1967
2005	685.4	686.0	686.8	685.5	684.2	1	1968
2006	687.6	687.2	685.9	684.2	682.5	1	1969

(Continued on next page.)

Appendix 1. Continued.

Group Run A--Regulated with Ice Dam Every 7 Years							
Year	Ecological Time Period					Trap	Year
	1	2	3	4	5	Code	Used
1971	684.5	686.0	687.0	686.0	684.0	0	----
1972	686.5	688.5	692.2	688.9	685.7	1	ICE DAM
1973	687.7	688.6	689.3	687.9	685.2	1	1965
1974	685.4	686.0	686.8	685.5	684.2	1	1968
1975	684.1	684.1	684.4	683.3	682.7	1	1970
1976	684.1	684.1	684.4	683.3	682.7	1	1970
1977	687.6	687.2	685.9	684.2	682.5	1	1969
1978	684.1	684.1	684.4	683.3	682.7	1	1970
1979	686.5	688.5	692.2	688.9	685.7	1	ICE DAM
1980	685.4	686.0	686.8	685.5	684.2	1	1968
1981	684.1	684.1	684.4	683.3	682.7	1	1970
1982	687.6	687.2	685.9	684.2	682.5	1	1969
1983	684.1	684.1	684.4	683.3	682.7	1	1970
1984	687.6	687.2	685.9	684.2	682.5	1	1969
1985	684.6	685.4	687.9	686.0	683.9	1	1971
1986	686.5	688.5	692.2	688.9	685.7	1	ICE DAM
1987	684.1	684.1	684.4	683.3	682.7	1	1970
1988	687.6	687.2	685.9	684.2	682.5	1	1969
1989	684.1	684.1	684.4	683.3	682.7	1	1970
1990	684.1	684.1	684.4	683.3	682.7	1	1970
1991	686.6	688.5	688.1	686.8	683.9	1	1967
1992	685.4	686.0	686.8	685.5	684.2	1	1968
1993	686.5	688.5	692.2	688.9	685.7	1	ICE DAM
1994	684.1	684.1	684.4	683.3	682.7	1	1970
1995	685.4	686.0	686.8	685.5	684.2	1	1968
1996	687.6	687.2	685.9	684.2	682.5	1	1969
1997	683.9	685.4	686.9	686.6	685.7	1	1960
1998	687.3	687.0	686.4	685.0	682.6	1	1961
1999	685.5	687.4	688.3	687.7	684.8	1	1962
2000	686.5	688.5	692.2	688.9	685.7	1	ICE DAM
2001	685.2	686.3	686.2	686.7	685.2	1	1964
2002	687.7	688.6	689.3	687.9	685.2	1	1965
2003	687.0	688.0	687.5	687.0	684.5	1	1966
2004	686.6	688.5	688.1	686.8	683.9	1	1967
2005	685.4	686.0	686.8	685.5	684.2	1	1968
2006	687.6	687.2	685.9	684.2	682.5	1	1969

Appendix 2. Average annual production, group run [illegible]. Numbers underlined indicate closest choice to natural regime.

	Average Over 35 Years				
	Natural Regime	Modified Regime	Rochers Weir	Rochers Constriction	Slave Constriction
Habitat Acres					
Open Water	508,442	413,113	580,387	690,864	629,438
Emergents	239,992	154,684	214,372	176,007	190,556
Duck Staging Habitat (Fall)	26,774	57,018	8,616	23,998	77,016
Mud Flats	11,624	12,127	7,979	22,511	15,506
Immature Fen	4,842	31,847	5,732	7,681	57,664
Carex Meadow	37,162	48,974	31,737	38,310	37,992
Calamagrostis Meadow	55,269	86,975	51,225	31,451	[illegible],951
Low Shrub	121,516	151,142	123,223	120,635	107,509
Tall Shrub	334,258	393,054	298,068	248,531	263,964
Deciduous	98,884	120,078	99,267	76,001	75,408
Shoreline Miles					
Perched Basins	5,875	2,946	4,407	5,448	4,613
Animal Numbers					
Dabblers	198,977	106,467	156,105	178,728	[illegible],260
Divers	94,414	47,285	74,902	80,805	62,655
Ducks	293,390	153,750	231,007	259,532	217,913
Muskrats (Spring)	59,153	15,292	50,622	22,318	6,456
Muskrats (Fall)	193,072	52,844	175,972	75,501	22,016
Carrying Capacity Muskrats	107,148	50,773	95,009	68,050	36,333
Carrying Capacity Moose	3,762	4,366	3,576	3,243	3,196
Carrying Capacity Bison	25,912	24,990	25,117	22,325	18,671

(Continued on next page.)

Appendix 2. Continued. Average annual production, group run B. Numbers underlined indicate closest choice to natural regime.

	Average Over 35 Years				
	Natural Regime	Modified Regime	Rochers Weir	Rochers Constriction	Slave Constriction
Habitat Acres					
Open Water	530,793	462,779	600,226	703,541	721,328
Emergents	272,089	172,883	230,886	220,535	187,433
Duck Staging Habitat (Fall)	18,362	36,265	9,125	16,539	57,751
Mud Flats	11,922	12,075	9,645	18,204	34,298
Immature Fen	7,181	19,839	9,126	12,797	15,864
Carex Meadow	36,661	57,113	33,715	46,985	42,608
Calamagrostis Meadow	38,471	75,859	44,916	27,001	26,123
Low Shrub	128,969	140,717	164,207	137,936	137,927
Tall Shrub	292,785	350,964	221,309	170,368	171,363
Deciduous	93,117	119,760	97,957	74,619	75,038
Shoreline Miles					
Perched Basins	6,918	3,499	4,660	5,899	4,681
Animal Numbers					
Dabblers	233,878	119,394	150,813	175,588	130,658
Divers	97,799	49,725	69,071	74,723	46,565
Ducks	331,679	169,118	219,882	250,311	177,225
Muskrats (Spring)	57,256	26,992	39,029	21,662	6,967
Muskrats (Fall)	178,453	93,051	131,772	73,188	22,408
Carrying Capacity Muskrats	118,167	78,477	130,594	150,511	62,912
Carrying Capacity Moose	3,481	3,946	3,359	2,955	2,973
Carrying Capacity Bison	28,360	26,659	27,153	23,856	21,321

(Continued on next page.)

Appendix 2. Continued. Average annual production, group run C. Numbers underlined indicate closest choice to natural regime.

	Average Over 35 Years				
	Natural Regime	Modified Regime	Rochers Weir	Rochers Constriction	Slave Constriction
<u>Habitat</u> <u>Acres</u>					
Open Water	487,759	385,064	<u>533,530</u>	625,457	569,000
Emergents	224,572	131,717	<u>231,507</u>	181,185	153,473
Duck Staging Habitat (Fall)	19,513	64,953	3,610	<u>20,326</u>	74,096
Mud Flats	8,055	<u>8,977</u>	2,990	20,310	15,832
Immature Fen	7,504	39,857	3,940	<u>5,689</u>	55,976
<u>Carex</u> Meadow	45,763	62,200	36,053	25,122	<u>36,436</u>
<u>Calamagrostis</u> Meadow	72,950	120,459	<u>73,287</u>	57,566	67,146
Low Shrub	136,875	<u>160,607</u>	177,802	208,773	226,311
Tall Shrub	325,767	<u>378,528</u>	245,368	201,628	206,777
Deciduous	102,744	124,585	<u>107,513</u>	86,258	81,041
<u>Shoreline</u> <u>Miles</u>					
Perched Basins	5,809	2,944	4,905	1,717	<u>4,976</u>
<u>Animal</u> <u>Numbers</u>					
Dabblers	226,338	110,120	<u>187,782</u>	40,086	175,758
Divers	94,550	49,157	<u>81,955</u>	51,889	64,510
Ducks	320,887	159,278	<u>269,736</u>	91,975	240,267
Muskrats (Spring)	53,721	15,132	<u>49,357</u>	36,767	17,975
Muskrats (Fall)	182,943	54,498	<u>171,599</u>	136,790	62,706
Carrying Capacity Muskrats	95,092	48,862	<u>91,164</u>	39,267	36,189
Carrying Capacity Moose	3,715	4,222	<u>3,568</u>	3,484	3,503
Carrying Capacity Bison	26,542	<u>25,705</u>	27,720	22,146	22,828

(Continued on next page.)

Appendix 2. Continued. Average annual production, group run D. Numbers underlined indicate closest choice to natural regime.

	Average Over 35 Years				
	Natural Regime	Modified Regime	Rochers Weir	Rochers Constriction	Slave Constriction
Habitat Acres					
Open Water	508,442	413,113	580,387	690,864	629,438
Emergents	239,992	154,684	214,372	176,007	190,556
Duck Staging Habitat (Fall)	26,774	57,018	8,616	23,998	77,016
Mud Flats	11,624	12,127	7,979	22,511	15,506
Immature Fen	4,842	3,847	5,732	7,681	57,664
Carex Meadow	37,162	48,974	31,737	38,310	37,992
Calamagrostis Meadow	55,269	86,975	51,225	31,451	33,951
Low Shrub	121,516	151,142	123,223	120,635	107,509
Tall Shrub	334,258	393,054	298,068	248,531	263,964
Deciduous	98,884	120,078	99,267	76,001	75,408
Shoreline Miles					
Perched Basins	5,875	2,946	4,407	5,448	4,613
Animal Numbers					
Dabblers	198,977	146,778	193,976	214,154	187,022
Divers	94,414	75,285	101,206	105,411	84,714
Ducks	293,390	222,065	295,181	319,565	271,737
Muskrats (Spring)	59,153	18,523	51,881	23,401	7,005
Muskrats (Fall)	193,072	66,155	186,116	81,952	24,654
Carrying Capacity Muskrats	107,148	50,773	95,009	68,050	36,333
Carrying Capacity Moose	3,762	4,366	3,576	3,243	3,196
Carrying Capacity Bison	25,912	24,990	25,117	22,325	18,671

(Continued on next page.)

Appendix 2. Continued. Average annual production, group run E. Numbers underlined indicate closest choice to natural regime.

	Average Over 35 Years				
	Natural Regime	Modified Regime	Rochers Weir	Rochers Constriction	Slave Constriction
Habitat Acres					
Open Water	447,050	387,947	499,715	578,374	543,267
Emergents	241,407	157,563	255,823	255,036	233,477
Duck Staging Habitat (Fall)	19,834	46,542	4,077	8,553	44,716
Mud Flats	5,316	8,984	2,471	8,859	15,073
Immature Fen	10,821	18,202	4,724	4,337	11,406
Carex Meadow	43,898	58,415	34,390	24,316	41,969
Calamagrostis Meadow	62,760	86,590	58,426	45,344	50,416
Low Shrub	139,239	158,413	120,824	124,429	136,526
Tall Shrub	355,532	410,585	323,090	271,345	282,570
Deciduous	105,968	125,292	112,526	99,950	97,287
Shoreline Miles					
Perched Basins	5,669	2,755	4,285	4,981	4,505
Animal Numbers					
Dabblers	203,607	146,077	197,942	201,334	198,030
Divers	99,009	77,407	110,296	97,357	111,391
Ducks	302,614	223,484	308,236	298,691	309,424
Muskrats (Spring)	81,193	32,769	77,512	56,320	59,269
Muskrats (Fall)	265,164	117,953	278,288	200,185	211,433
Carrying Capacity Muskrats	158,527	78,506	164,579	154,684	104,771
Carrying Capacity Moose	3,892	4,495	3,697	3,485	3,606
Carrying Capacity Bison	26,759	26,640	26,969	26,175	27,688

(Continued on next page.)

Appendix 2. Continued. Average annual production, group run F.

	Average over 35 Years	
	Natural	Regulated
Habitat Acres		
Open Water	507,986	418,221
Emergents	228,860	147,697
Duck Staging Habitat (Fall)	37,222	61,158
Mud Flats	19,015	12,761
Immature Fen	7,077	36,176
Carex Meadow	45,974	61,051
Calamagrostis Meadow	59,122	91,479
Low Shrub	138,090	152,198
Tall Shrub	310,213	372,869
Deciduous	95,653	119,545
Shoreline Miles		
Perched Basins	5,948	2,978
Animal Numbers		
Dabblers	213,706	149,279
Divers	84,119	73,561
Ducks	297,826	222,838
Muskrats (Spring)	50,667	20,481
Muskrats (Fall)	172,237	74,380
Carrying Capacity Muskrats	118,678	64,418
Carrying Capacity Moose	3,595	4,143
Carrying Capacity Bison	27,339	26,314

(Continued on next page.)

Appendix 2. Continued. Average annual production, group run G

	Average over 70 Years	
	Natural	Regulated
Habitat Acres		
Open Water	533,597	415,269
Emergents	187,723	155,778
Duck Staging Habitat (Fall)	54,368	60,426
Mud Flats	26,922	12,071
Immature Fen	4,867	29,548
Carex Meadow	34,009	41,948
Calamagrostis Meadow	48,375	67,537
Low Shrub	83,413	97,065
Tall Shrub	220,727	251,337
Deciduous	272,352	341,439
Shoreline Miles		
Perched Basins	5,581	2,619
Animal Numbers		
Dabblers	193,838	142,685
Divers	83,461	80,655
Ducks	277,296	223,340
Muskrats (Spring)	54,585	29,849
Muskrats (Fall)	184,285	109,402
Carrying Capacity Muskrats	94,831	54,846
Carrying Capacity Moose	3,770	4,494
Carrying Capacity Bison	24,337	23,672

(Continued on next page.)

pendix 2. Continued. Average annual production, group run H.

	Average over 70 Years	
	Natural	Regulated
bitat Acres		
en Water	484,166	406,312
ergents	218,207	154,363
ck Staging Habitat (Fall)	36,855	54,901
d Flats	14,680	11,448
mature Fen	6,897	16,913
rex Meadow	32,013	44,735
lamagrostis Meadow	45,135	59,531
w Shrub	89,353	99,962
ll Shrub	236,255	265,326
ciduous	285,281	353,393
oreline Miles		
rched Basins	5,447	2,517
imal Numbers		
bblers	188,419	141,169
vers	92,474	84,164
cks	280,893	225,333
skrats (Spring)	89,862	35,436
skrats (Fall)	296,503	128,946
rrying Capacity Muskrats	134,289	58,887
rrying Capacity Moose	3,988	4,705
rrying Capacity Bison	24,482	24,551

Fig.5

MAJOR HABITAT TYPES

PEACE-ATHABASCA DELTA

FALL 1970